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Soil Water Measurements Relevant to Agronomic and Environmental Functions of Chemically-Treated Soil

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What We'll Cover

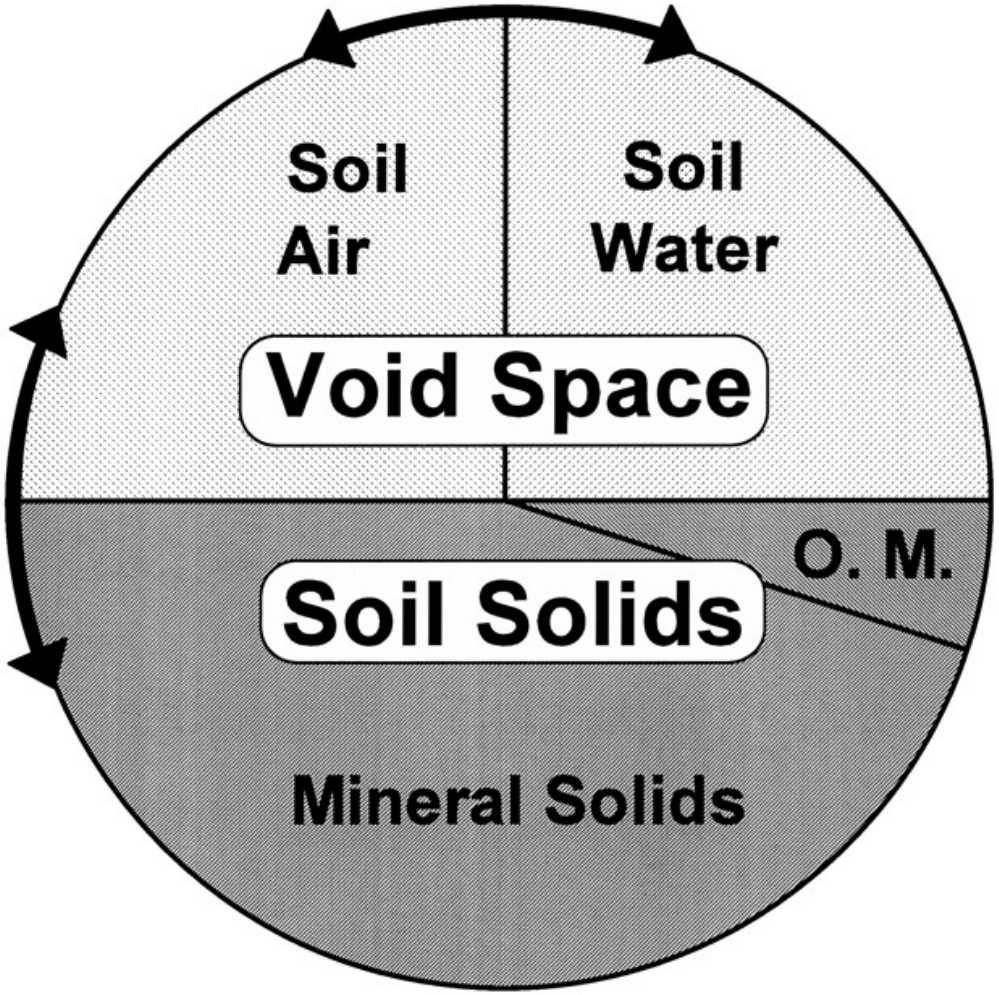
- Basic 3-phase Soil Physical Model
- 3 Categories of Soil Water Quantification
- Interpretation & Application of Each
- Basic Instrumentation
- Implications for Solute Flow & Miscible Displacement

PLEASE
Read the Paper
for a more scholarly, documented presentation

The paper will appear in the ASTM Special Technical Publication and in the Journal of ASTM International (JAI). Reprints will eventually appear on our website's publication list (probably early 2008).

Special thanks to the many web sources for images borrowed for this educational presentation.

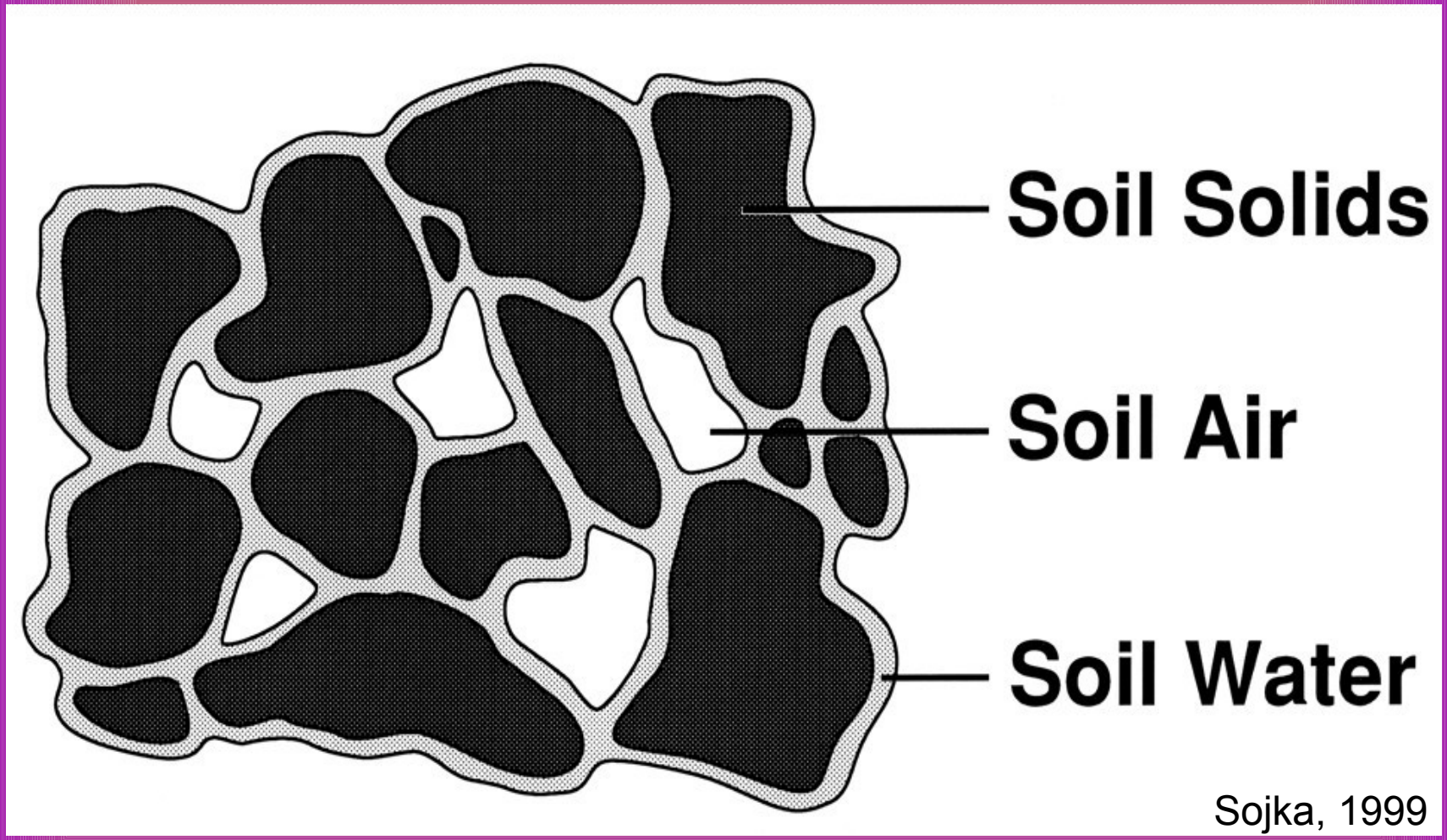
Three Phase Soil Model



Soil Organic Matter Typically 1-5%

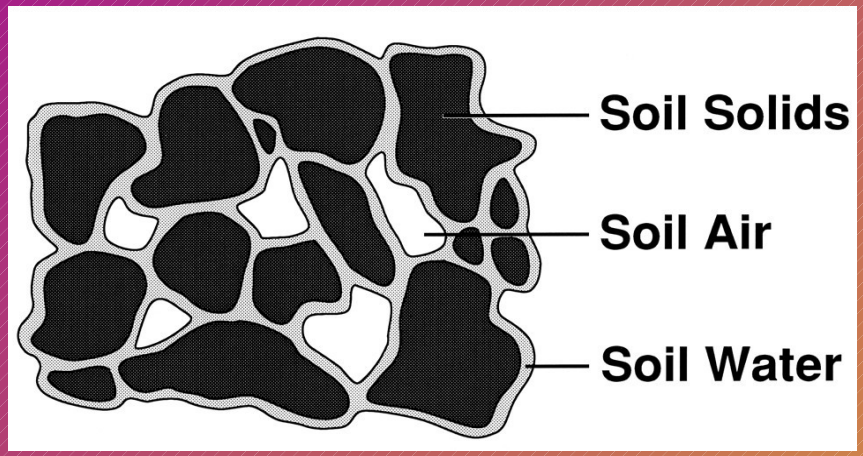
Sojka, 1999

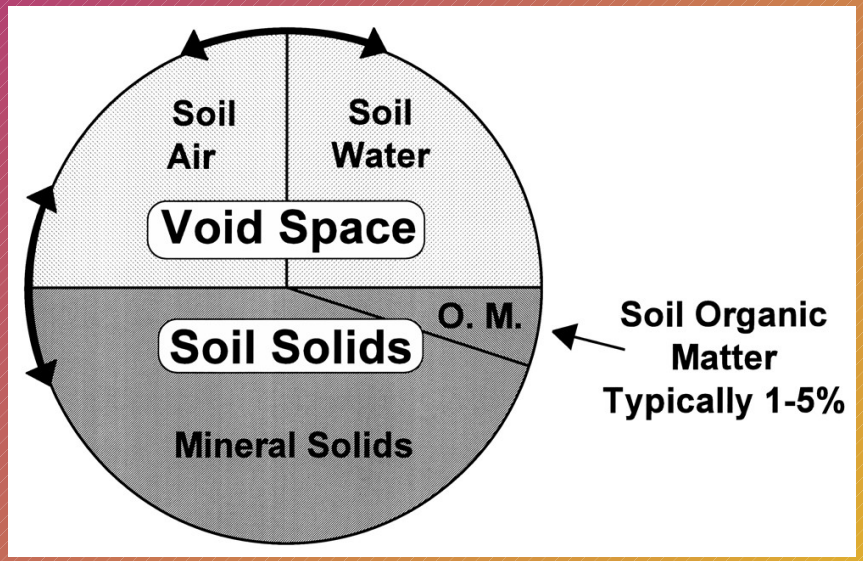
Three Phase Soil Model



Sojka, 1999

Three Phase Soil Model





SOIL AERATION:

O_2 diffuses in through water only one ten-thousandth as easily as through soil air

Many plant responses and soil status transformations are mistaken as direct responses to chemical application, when they may actually be aeration effects.

Poor aeration most often results from excess soil water, and can exacerbated by high temperature, compaction or fresh incorporation of organic matter

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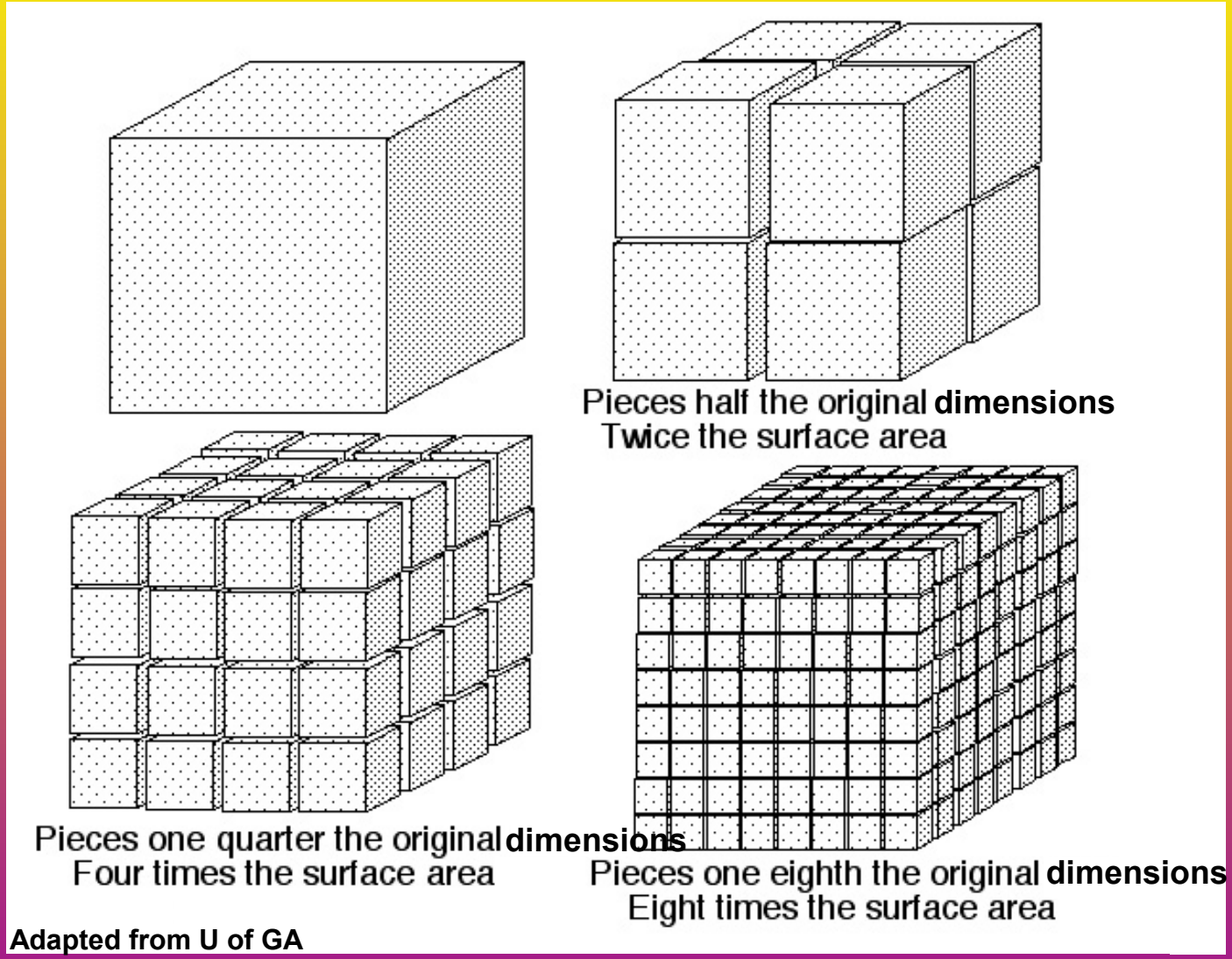
3 Categories of Soil Water Quantification

Content

Energy

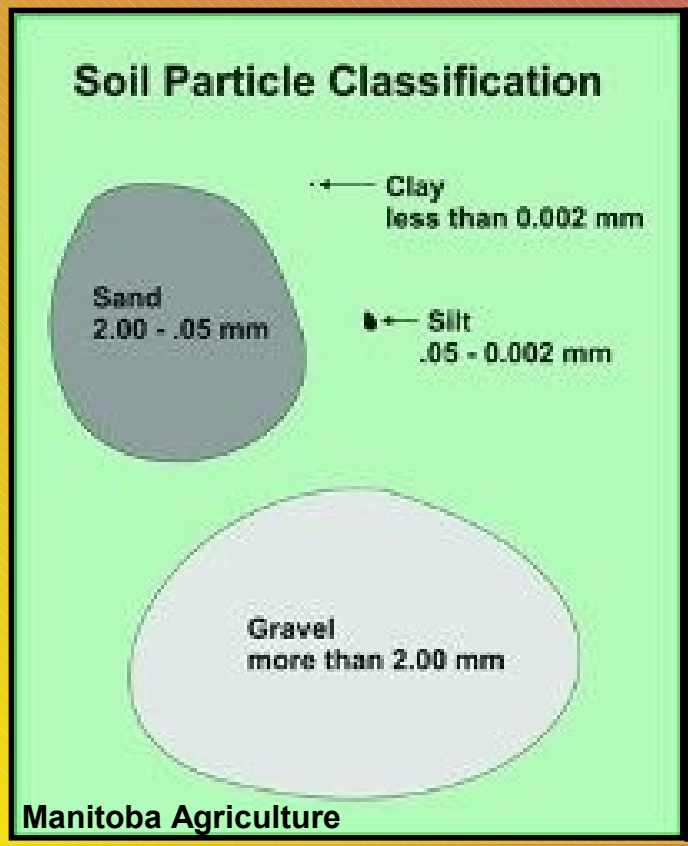
Flow

Particle Size and Surface Area

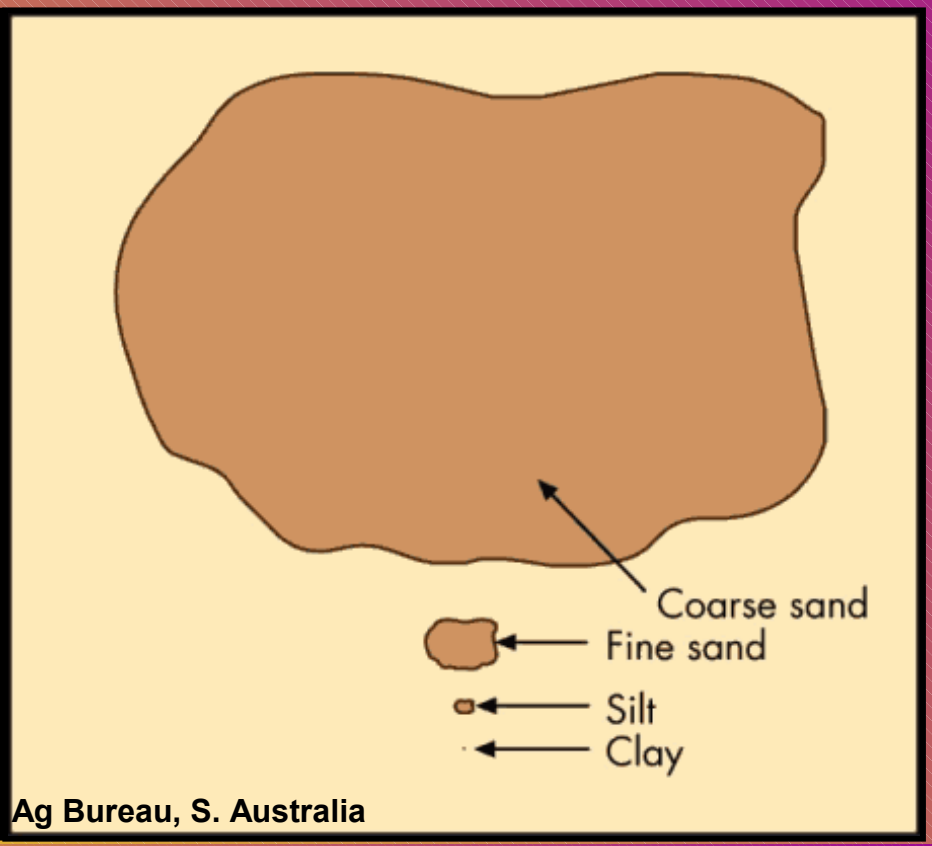


Adapted from U of GA

Primary Particle Size (Minerals Only)



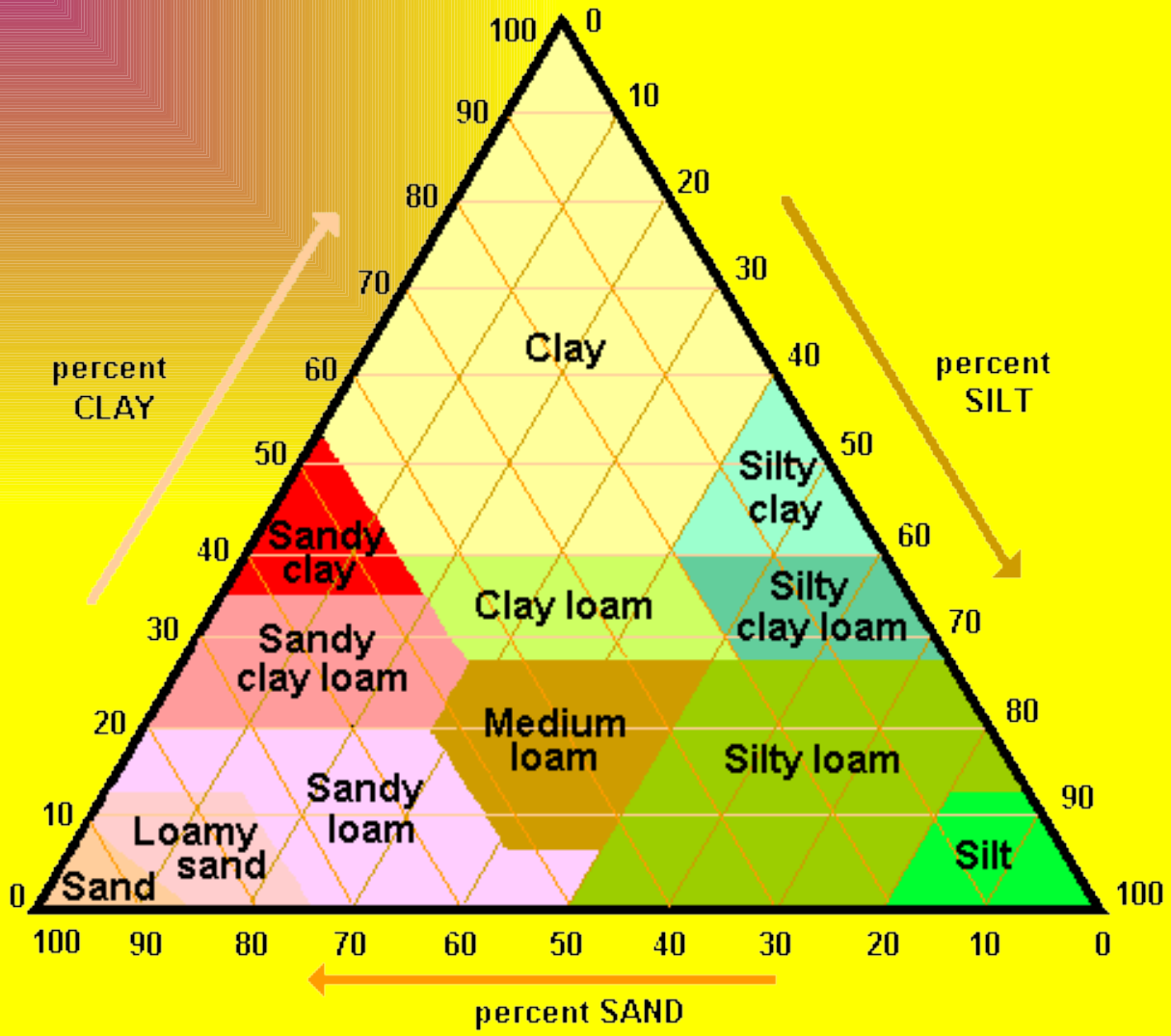
Manitoba Agriculture



Ag Bureau, S. Australia

Clay < 0.002 mm, Silt 0.002-0.05 mm, Very Fine Sand 0.05-0.10 mm, Fine Sand 0.10-0.25 mm, Medium Sand 0.25-0.5 mm, Coarse Sand 0.5-1.0 mm, Very Coarse Sand 1-2 mm, Gravel 2-75 mm

Textural Triangle (Minerals Only)



Idaho Oneplan

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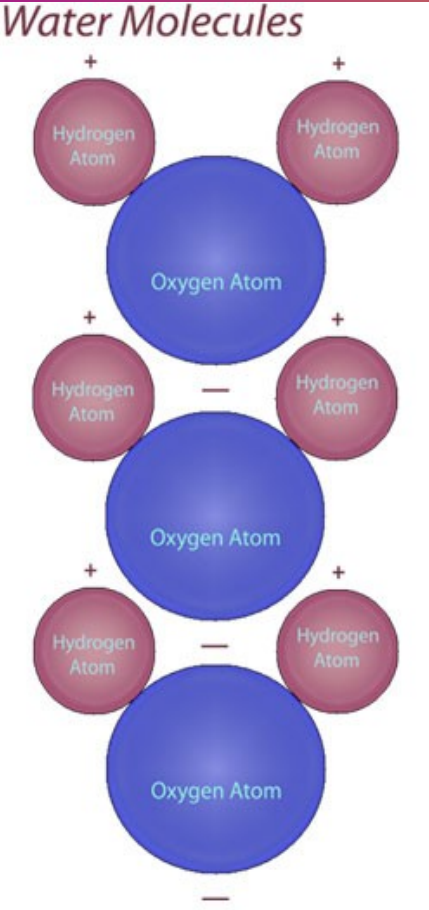
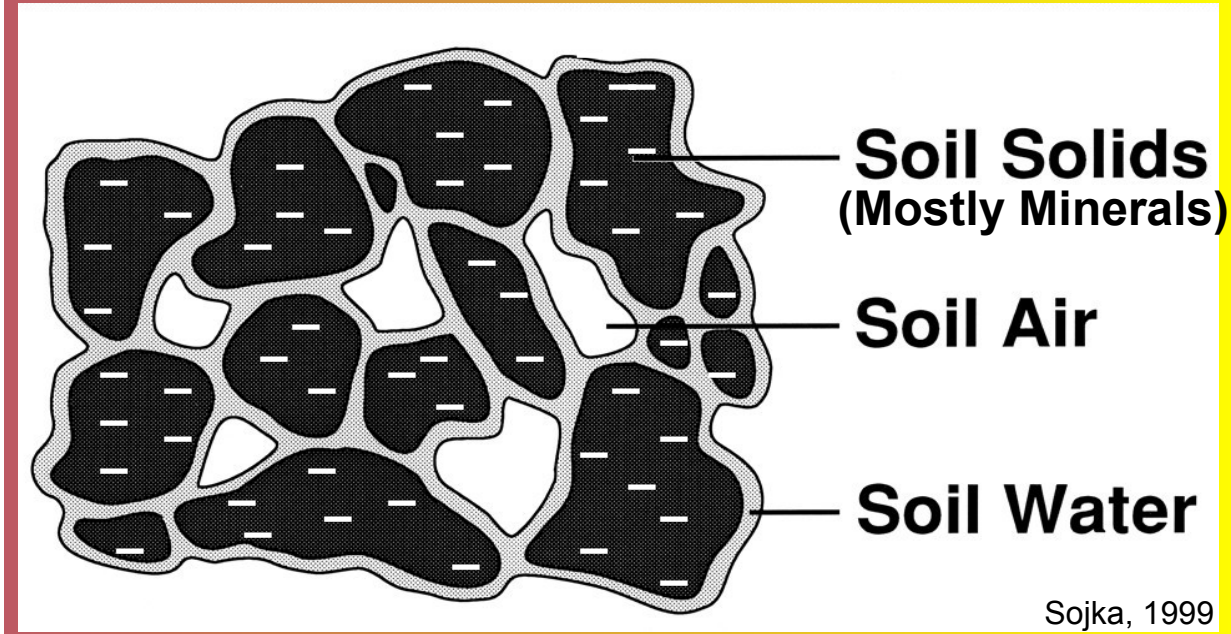
Water Is a Dipole, and Soil Minerals Are Mostly Negatively Charged



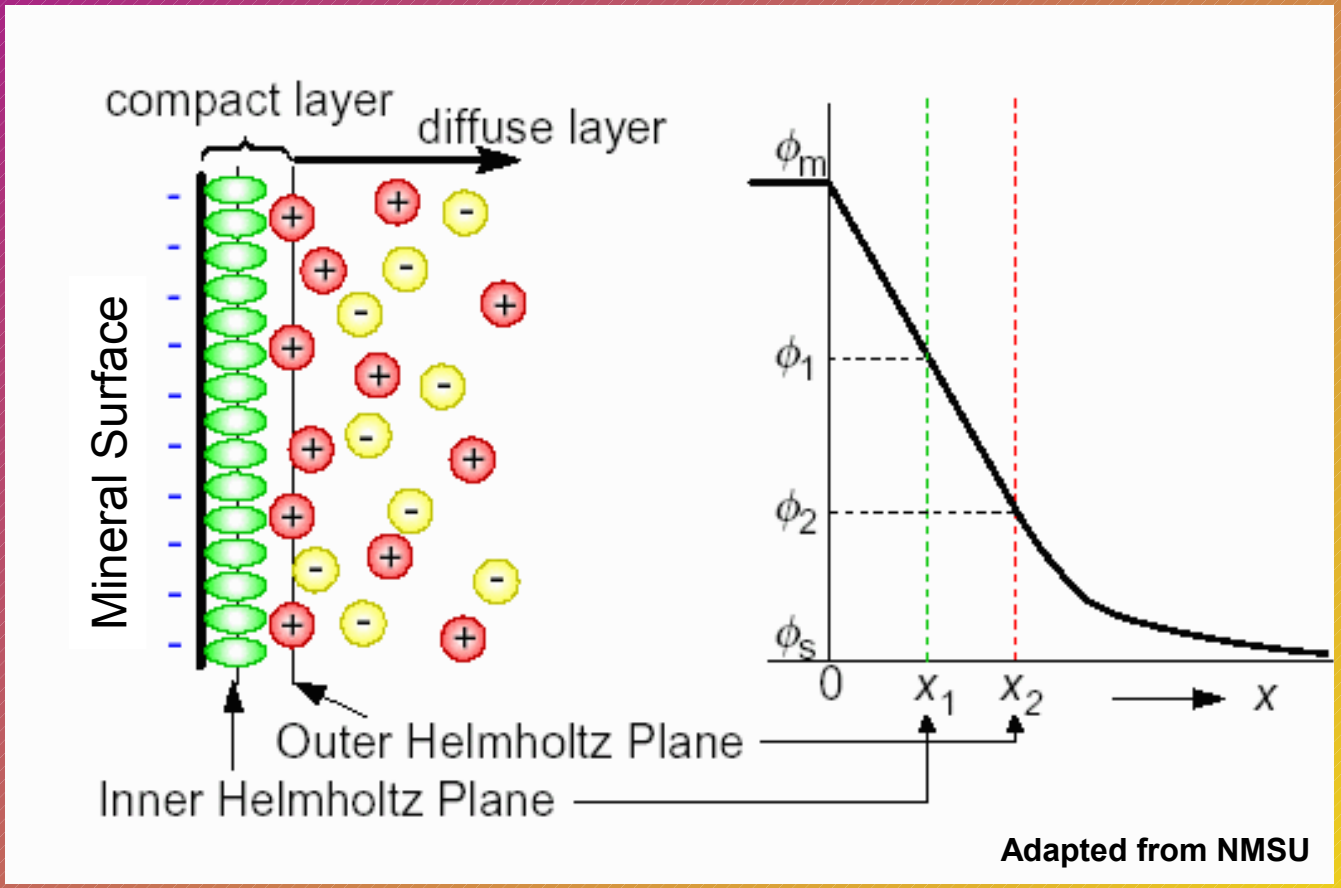
ID Museum of Nat. History

Hydrogen Bonding Occurs Between Protons & Mineral Surfaces



Sojka, 1999

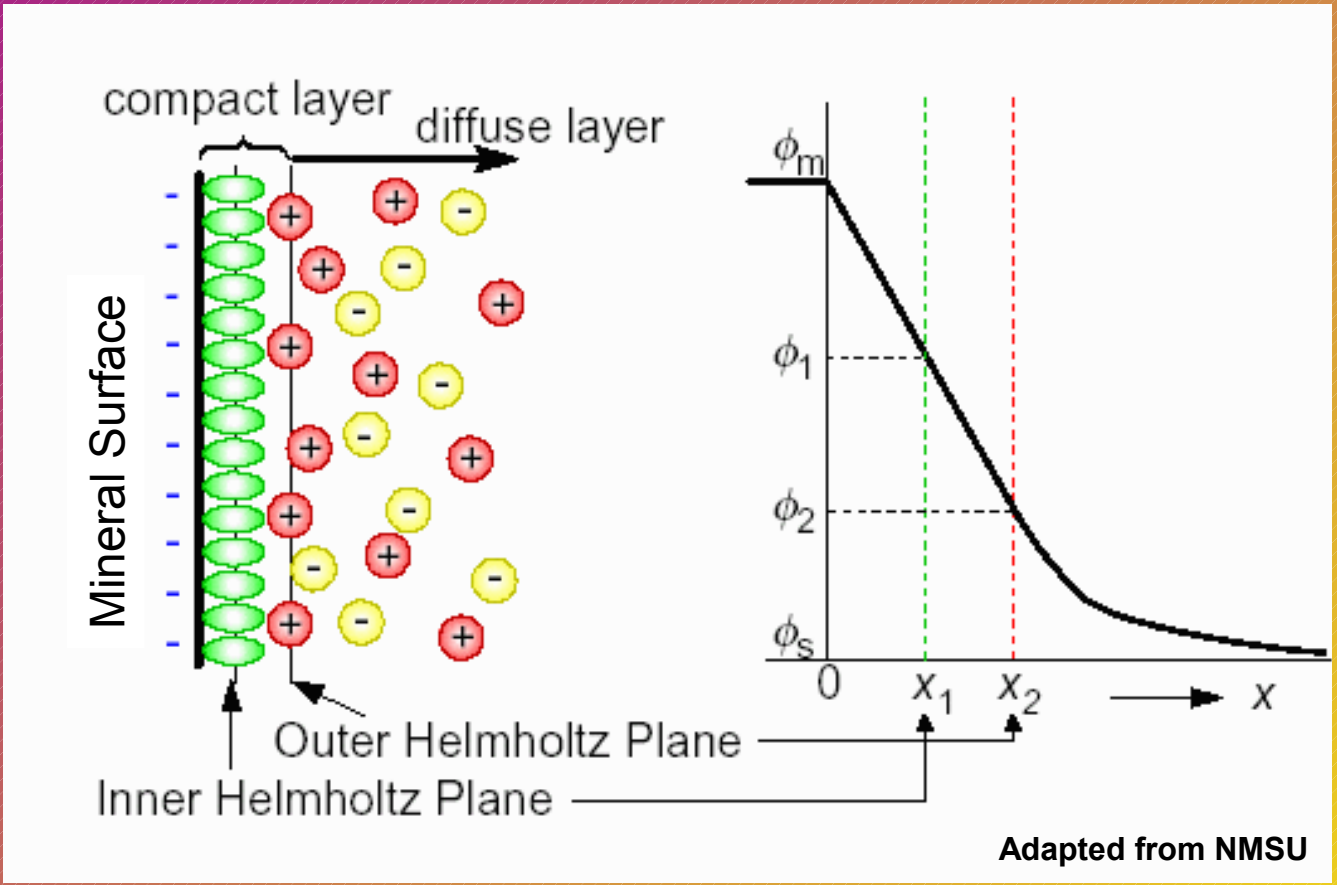
Water & Solute Retention



Adapted from NMSU

Attraction for Water and Solutes Decreases with Distance from Mineral surfaces. The potential at the Beginning of the Diffuse Layer is called the Zeta Potential

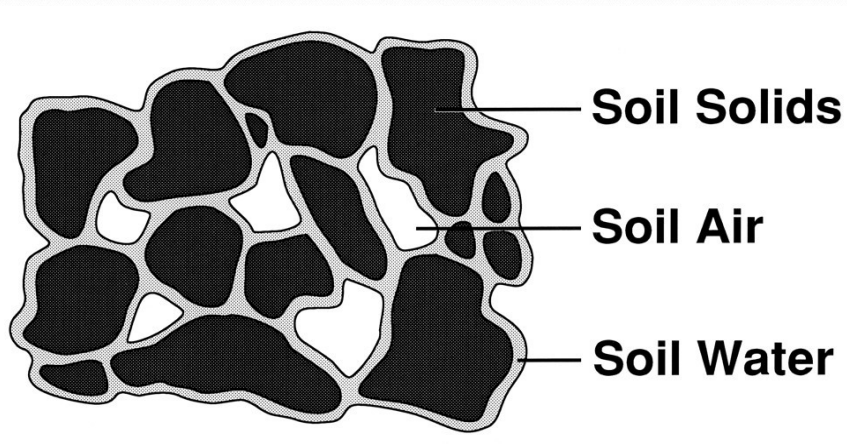
Water & Solute Retention

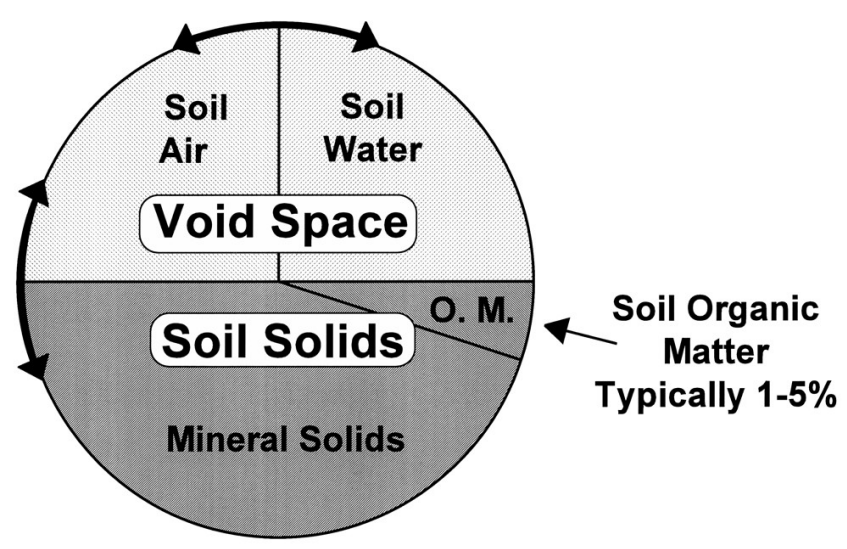


Adapted from NMSU

This Is Why Smaller Pores Have Greater Water Retention (Capillarity) and Why Soil with Greater Surface Area (clay soils) Retain More Water and Solutes Than Soils with Less Surface Area (sands)

Three Phase Soil Model





WATER RETENTION:

PORE SIZE affects water retention *at a given water potential*.

If average pore size is small, water is more subject to capillary retention, so more water is present at greater suction (more negative [lower] water potential). Water can be available over a longer drying period…

Clays have mostly small pores.

Sands have mostly large pores.

Structured (aggregated) soils have both.

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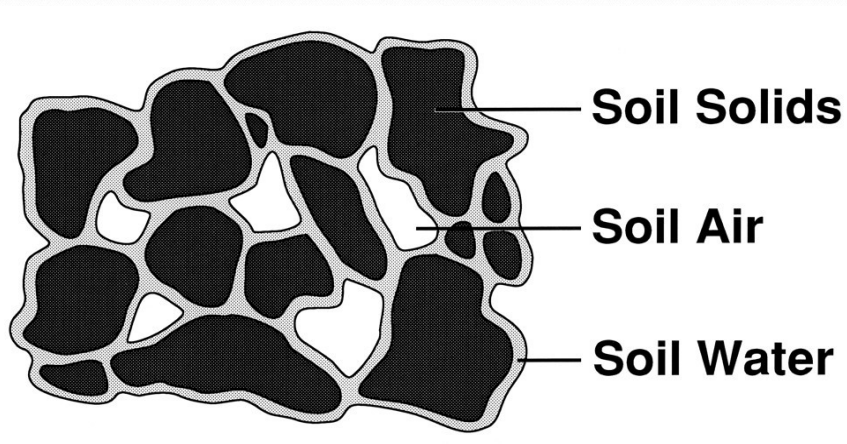
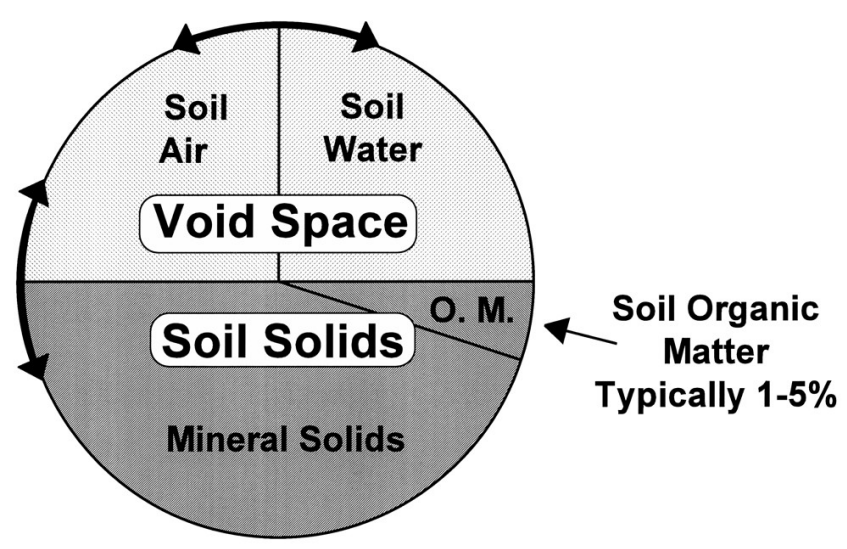
Three Phase Soil Model





WATER RETENTION:

TOTAL PORE VOLUME affects maximum water storage capacity (zero water potential-- saturation).

Clays have small pores, but the largest total pore space & hold the largest total volume of water (weigh more wet = “heavy soil”).

Sands have larger pores than clays, but low total pore space & hold least total volume of water (weigh less wet = “light soils”).

Structured soils are intermediate. The largest pores are larger than in sand, but the effect is offset by small pores inside aggregates.

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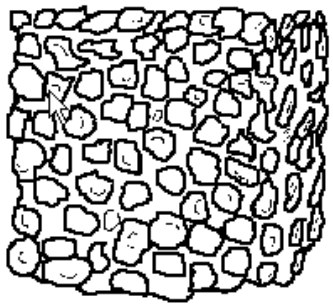
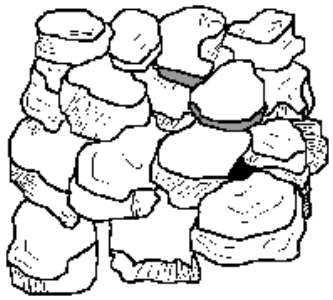
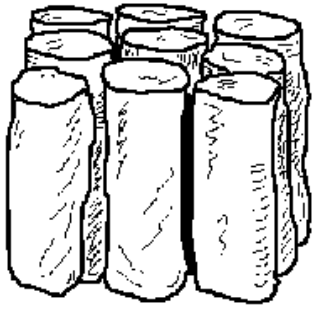
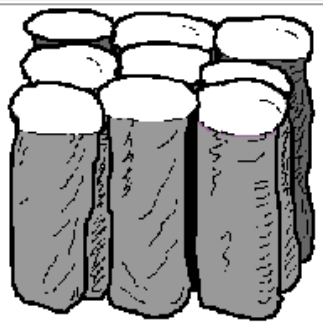
Soil Structure

		
Granular: Resembles cookie crumbs and is usually less than 0.5 cm in diameter. Commonly found in surface horizons where roots have been growing.	**Blocky**: Irregular blocks that are usually 1.5 - 5.0 cm in diameter.	**Prismatic**: Vertical columns of soil that might be a number of cm long. Usually found in lower horizons.
		
Columnar: Vertical columns of soil that have a salt "cap" at the top. Found in soils of arid climates.	**Platy**: Thin, flat plates of soil that lie horizontally. Usually found in compacted soil.	**Single Grained**: Soil is broken into individual particles that do not stick together. Always accompanies a loose consistence. Commonly found in sandy soils.

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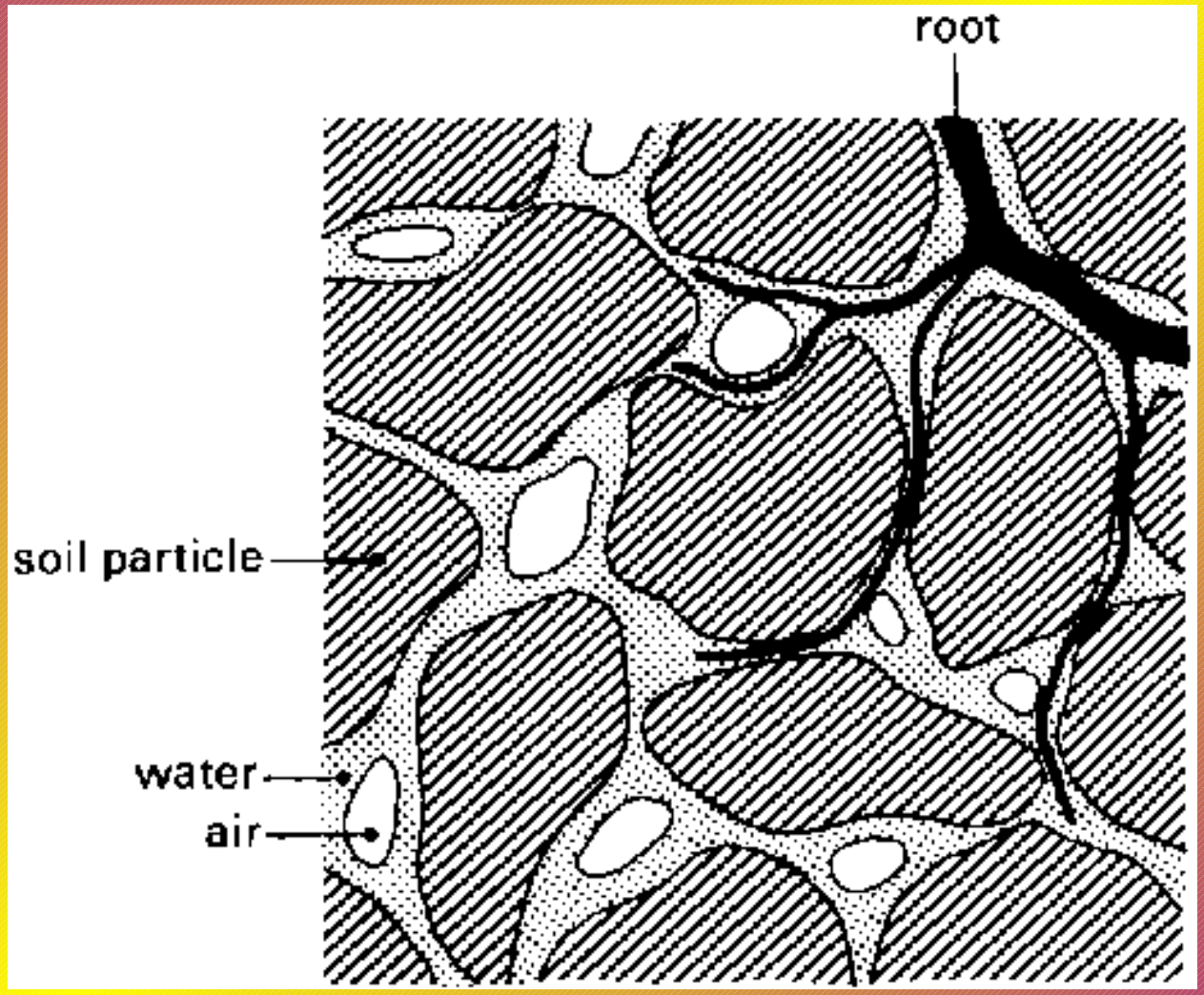
Soil Structure & Roots



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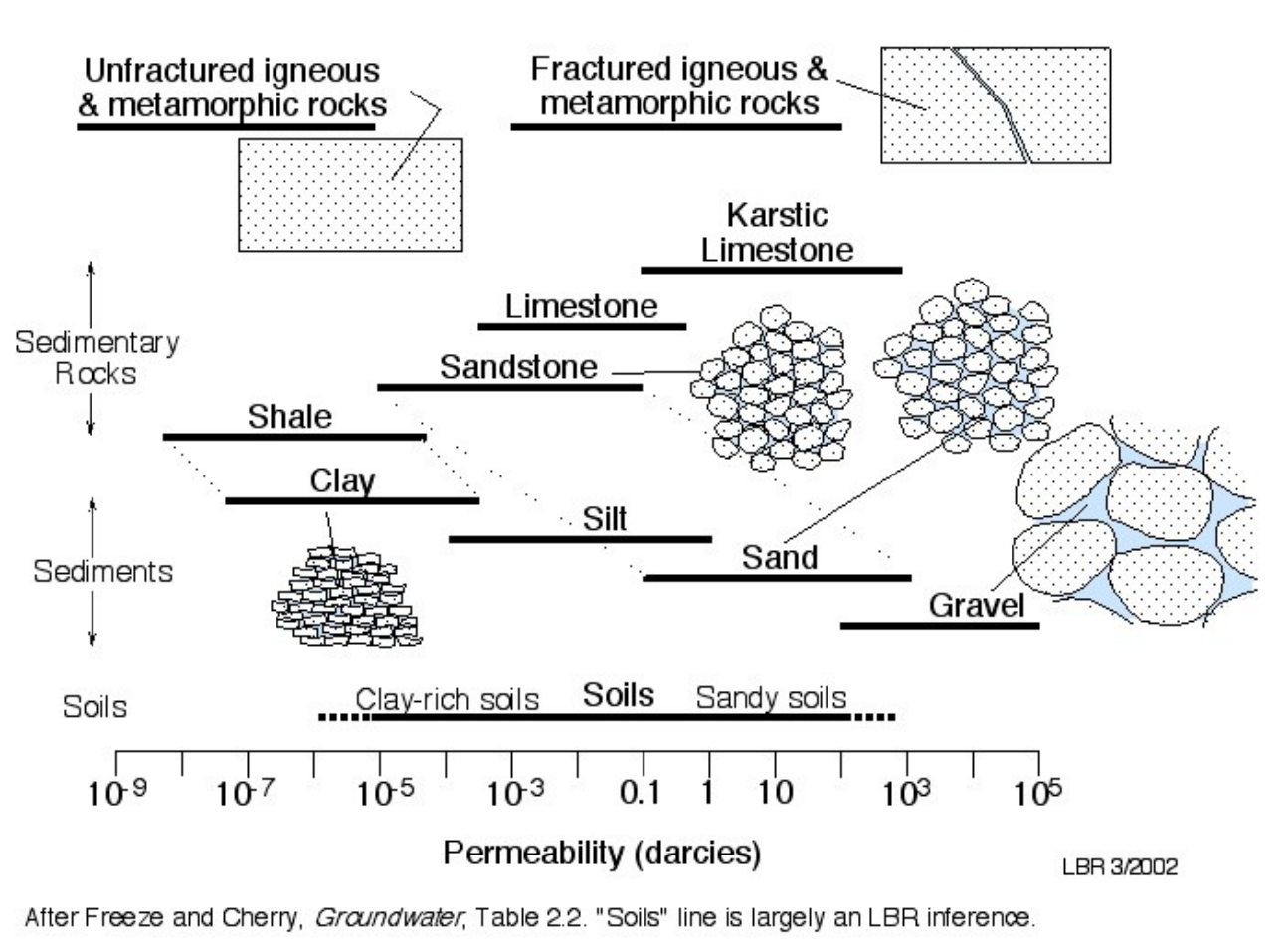
Structure and Conductivity



After Freeze and Cherry, *Groundwater*, Table 2.2. "Soils" line is largely an LBR inference.

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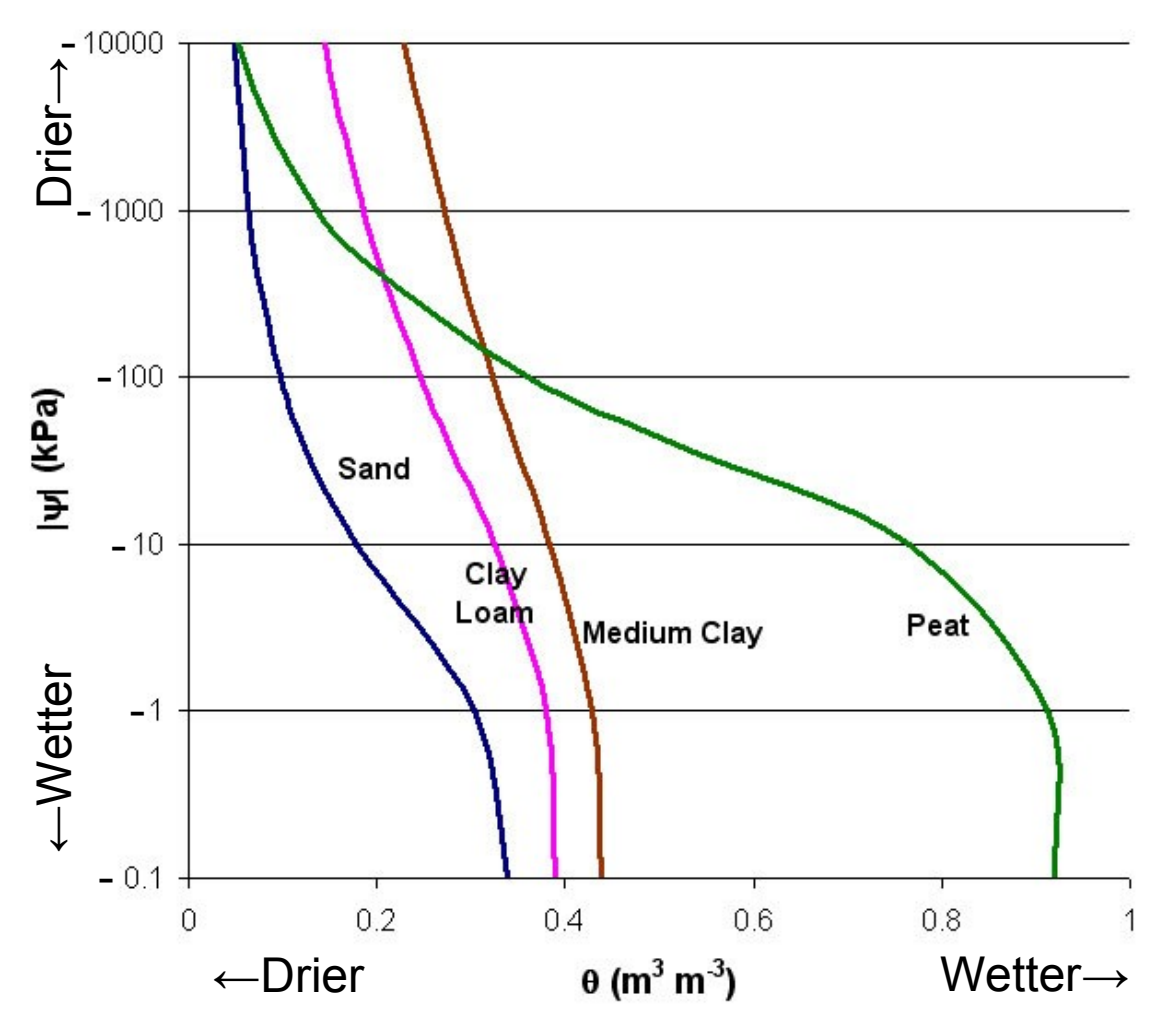
U of GA, after Freeze and Cherry

Texture & Water Retention

↑
SUCTION
or
TENSION

"Negative Potential, Positive Foolishness"



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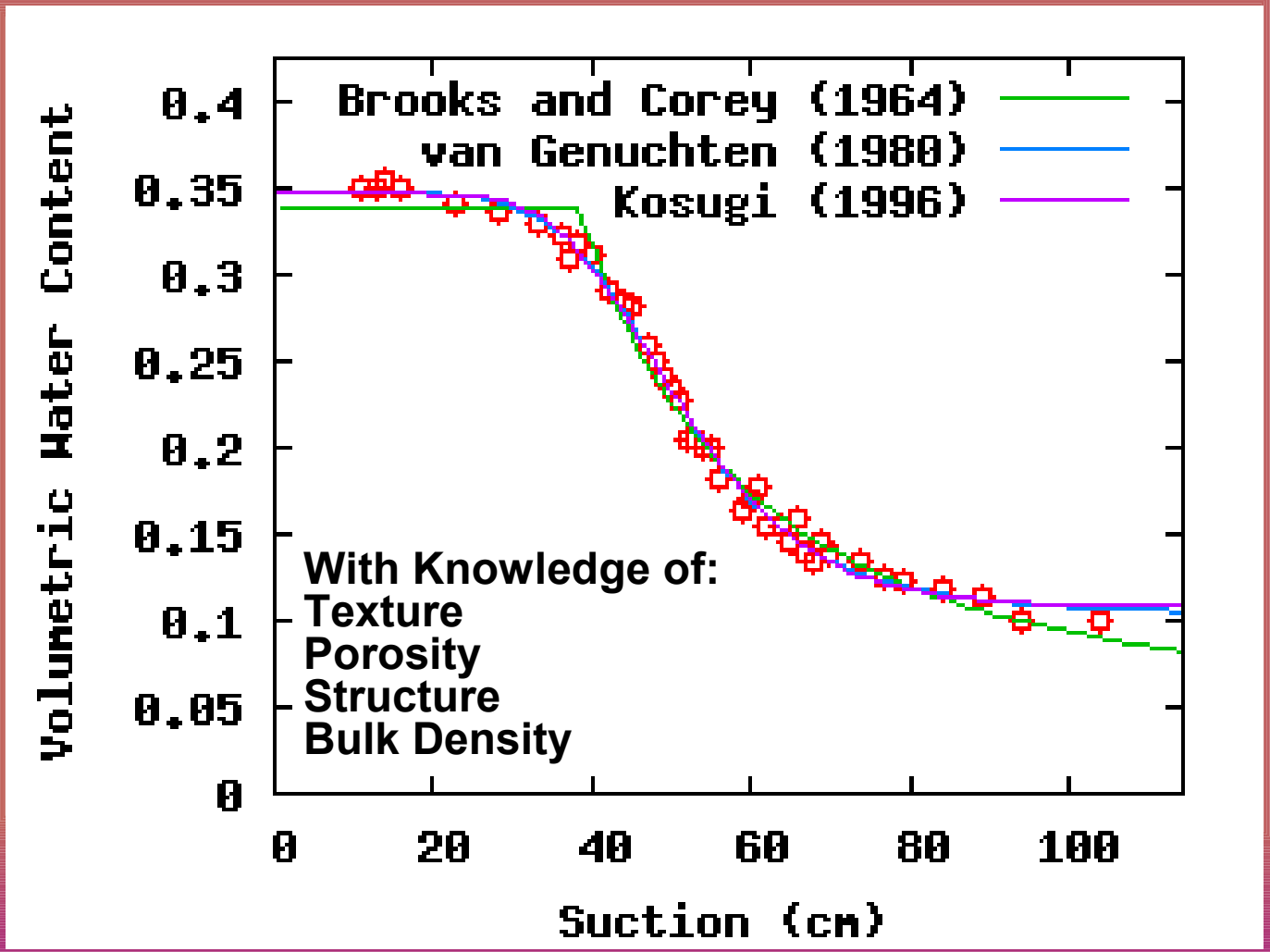
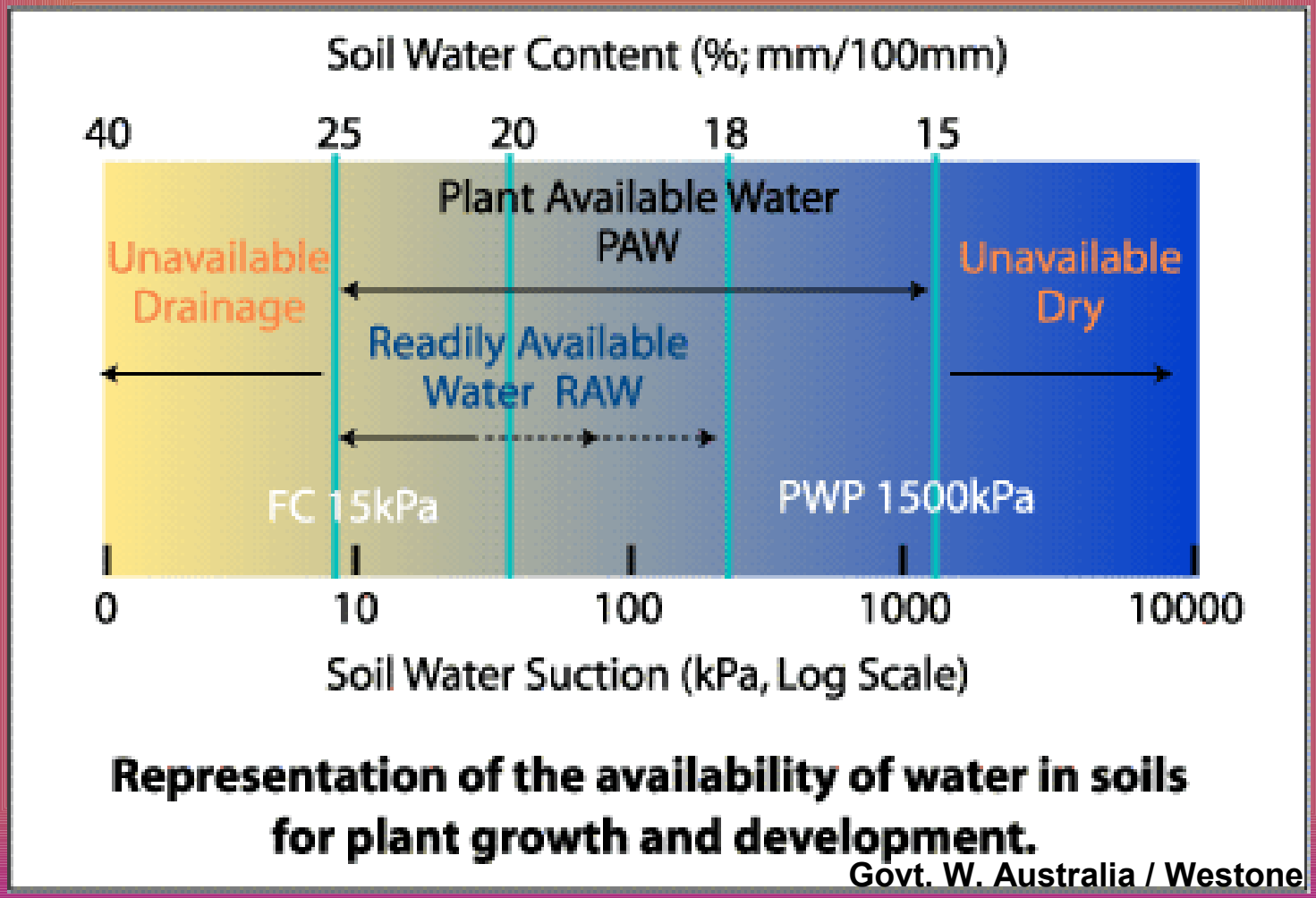
Adapted from Wikipedia

Water Retention Can Be Modeled



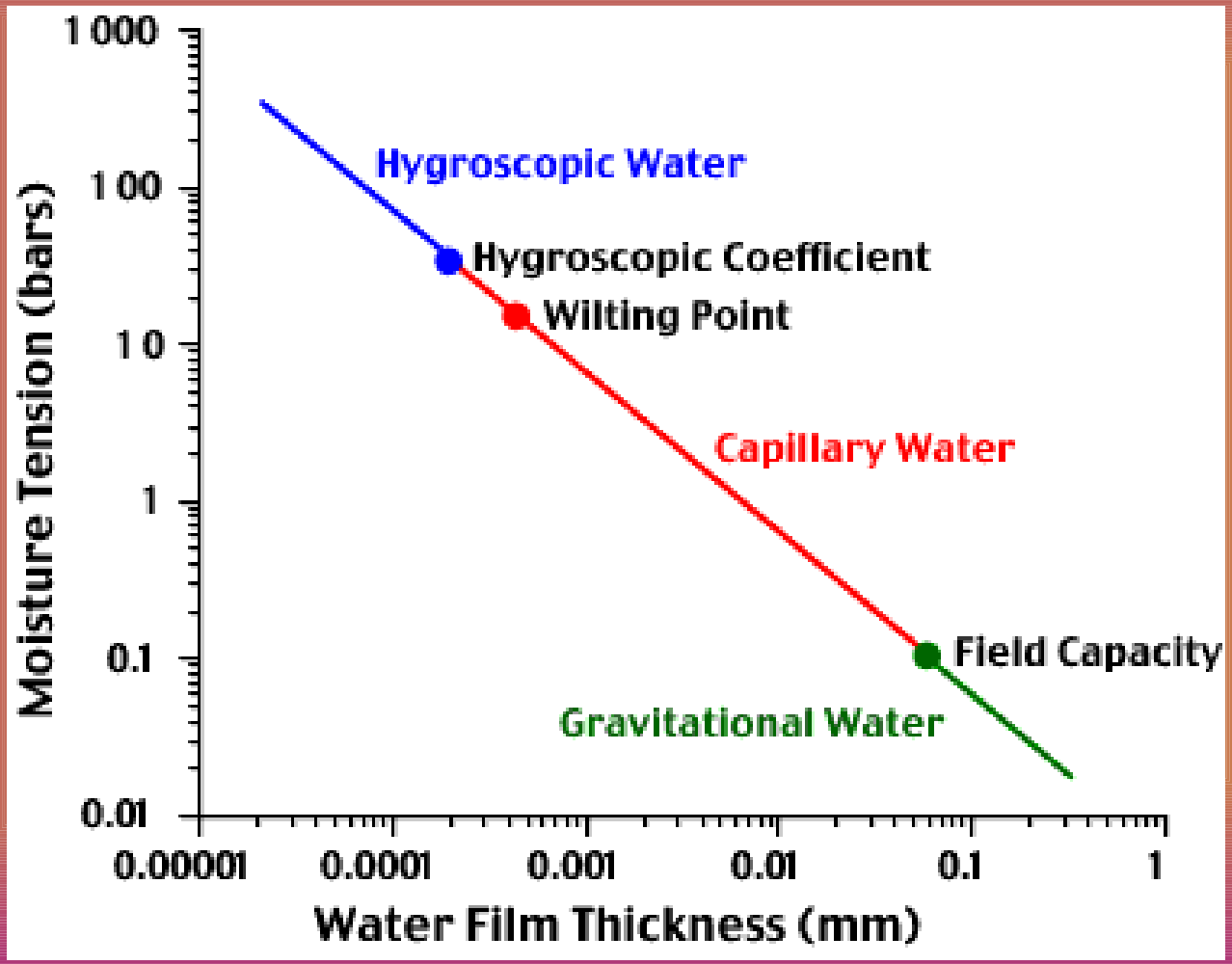
Water Retention Relates to Plant Growth and Stress



Representation of the availability of water in soils for plant growth and development.

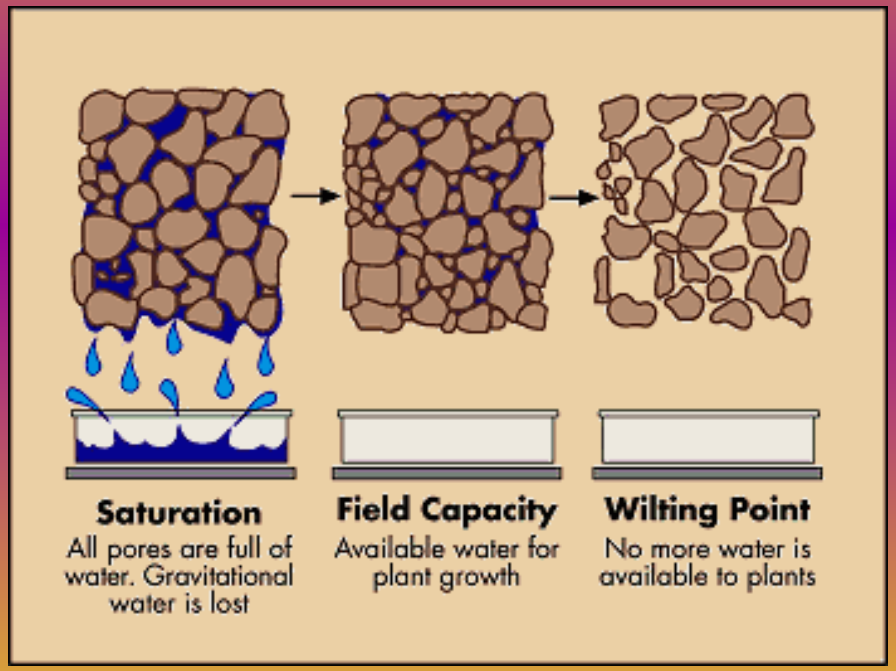
Govt. W. Australia / Westone

Water Retention Relates to Plant Growth and Stress

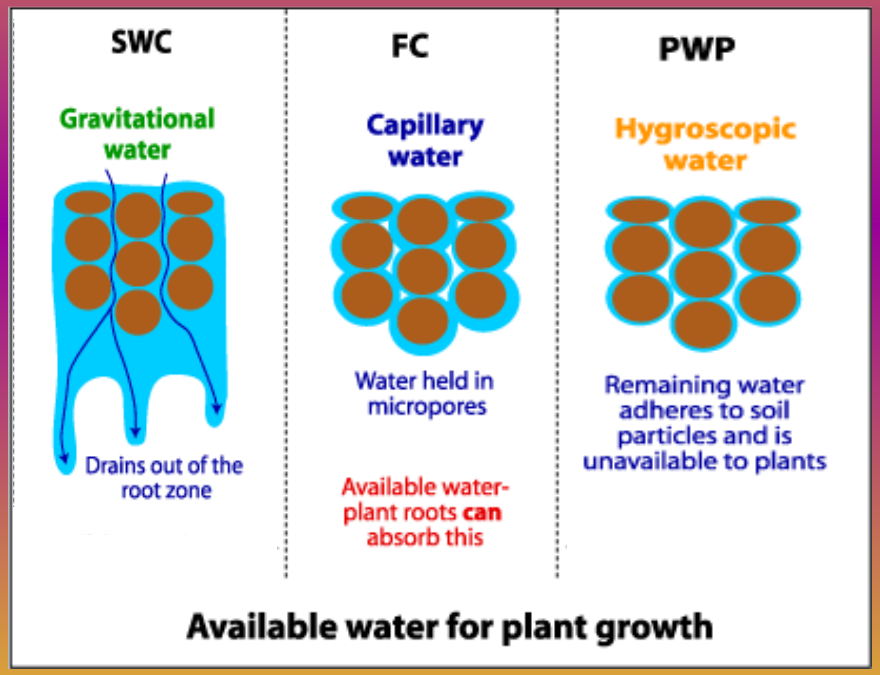


M. Pidwerny, U of BC

Saturation Water Content
Field Capacity
Permanent Wilting Point



Agricultural Burea, West. Austr.



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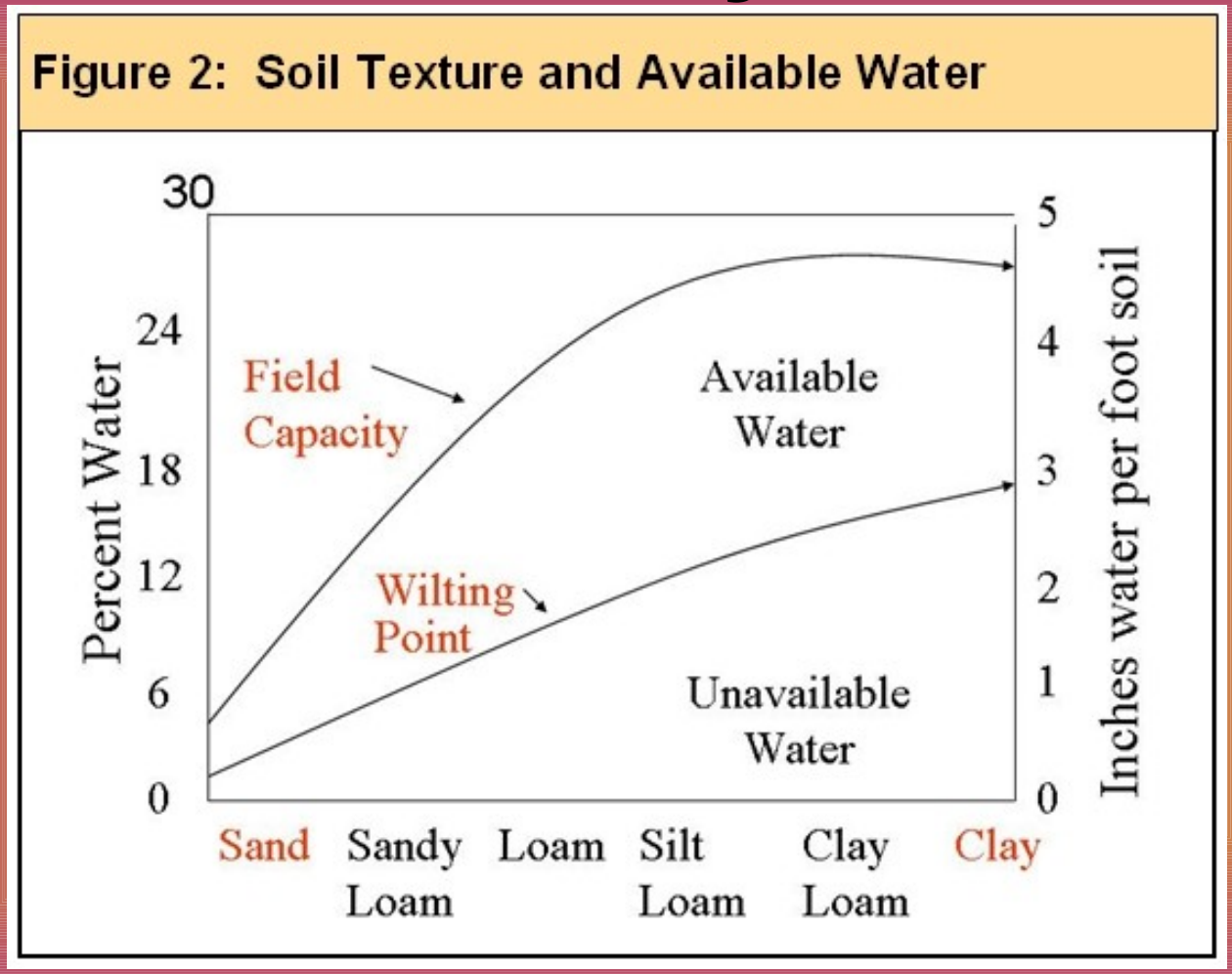
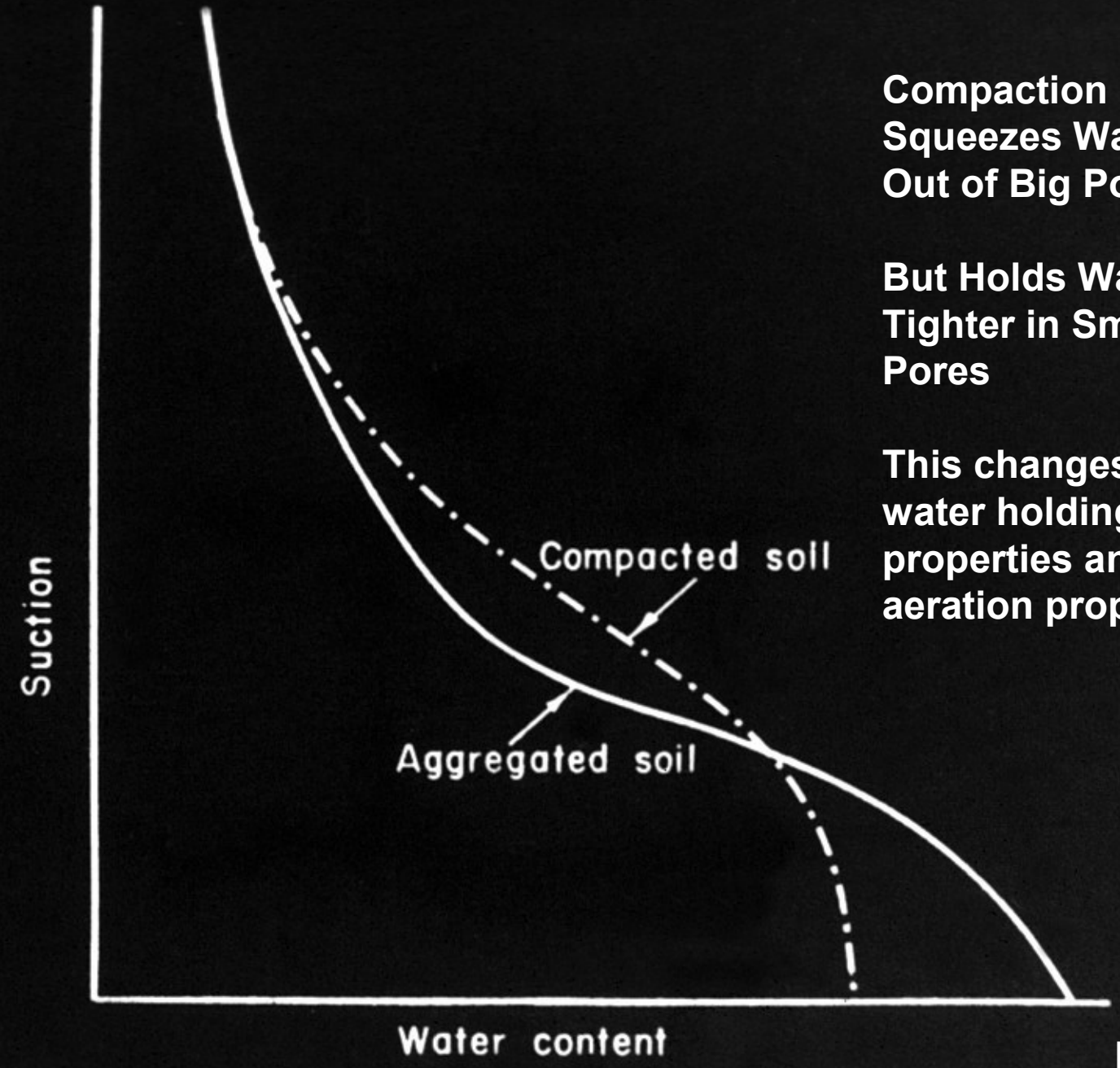
Water Availability and Texture



University of MN



Compaction Squeezes Water Out of Big Pores

But Holds Water Tighter in Small Pores

This changes water holding properties and soil aeration properties

Hillel, 1971

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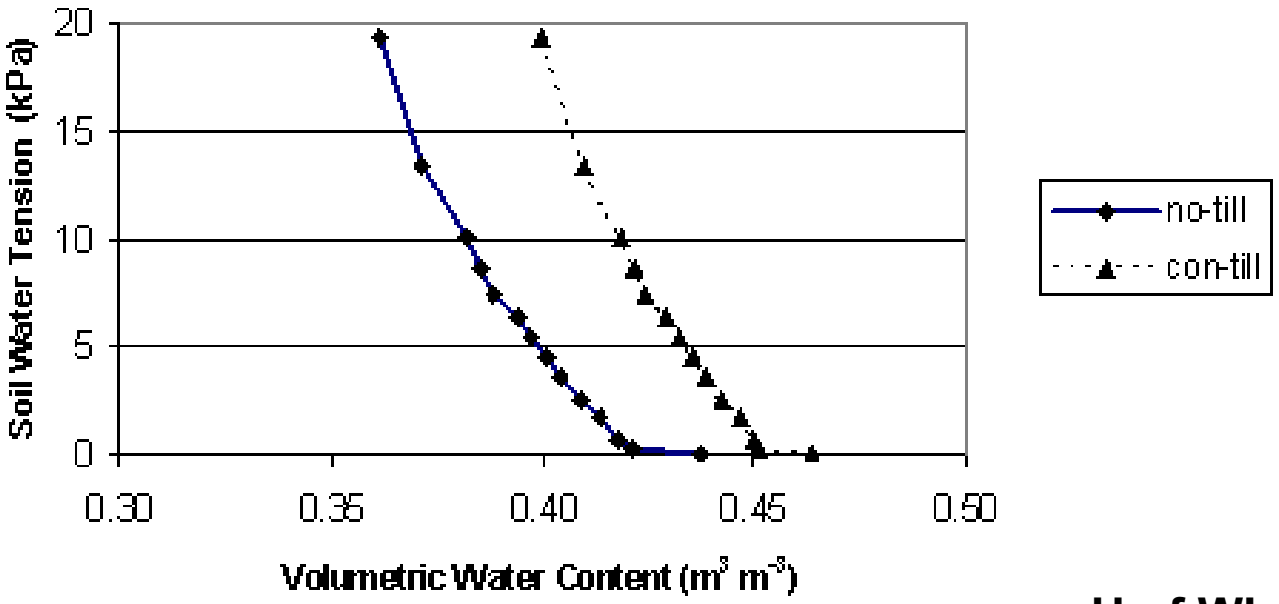
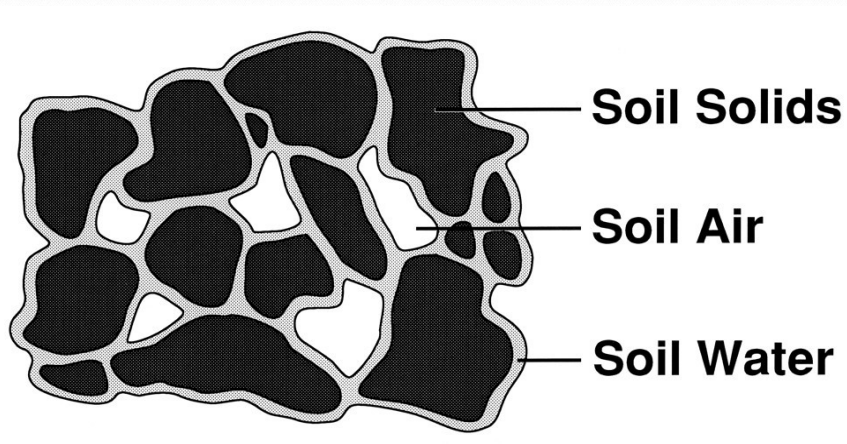
Tillage Alters Structure, Changing Water Retention

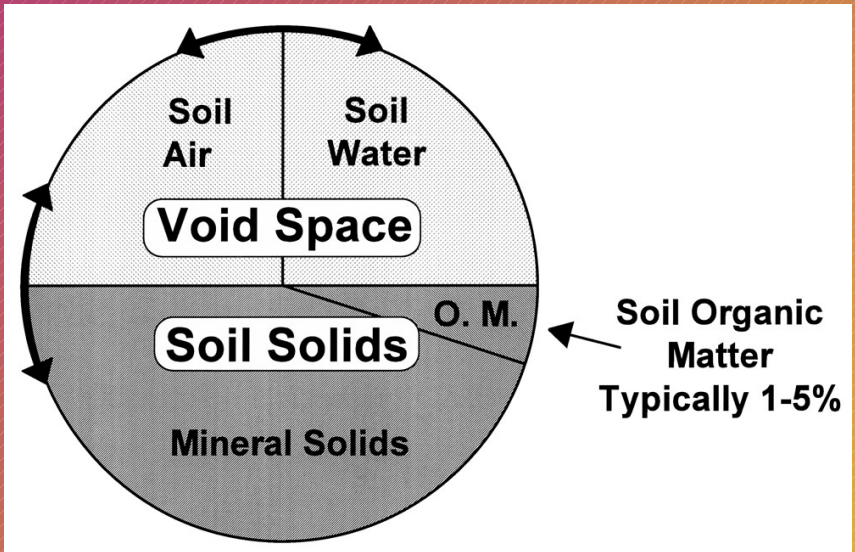
Figure 3. Volumetric water content and soil water tension in No-till (CS-2) and Conventional Tillage (CS-5) in the year 2002.



U of WI

Three Phase Soil Model





HYDRAULIC CONDUCTIVITY (internal water flow / drainage)

Soil Texture & Structure Affect Pore Space, Size, Arrangement, and Continuity

Small pores: Less water flow at saturation. But… Water is more subject to capillary action, so more water flows in the dryer range (up to a point).

Large pores: water flows freely at saturation. Less capillarity greatly reduces flow in the dry range (low water potential)

Aggregated soils have a mixture of pore sizes and intermediate flow behavior

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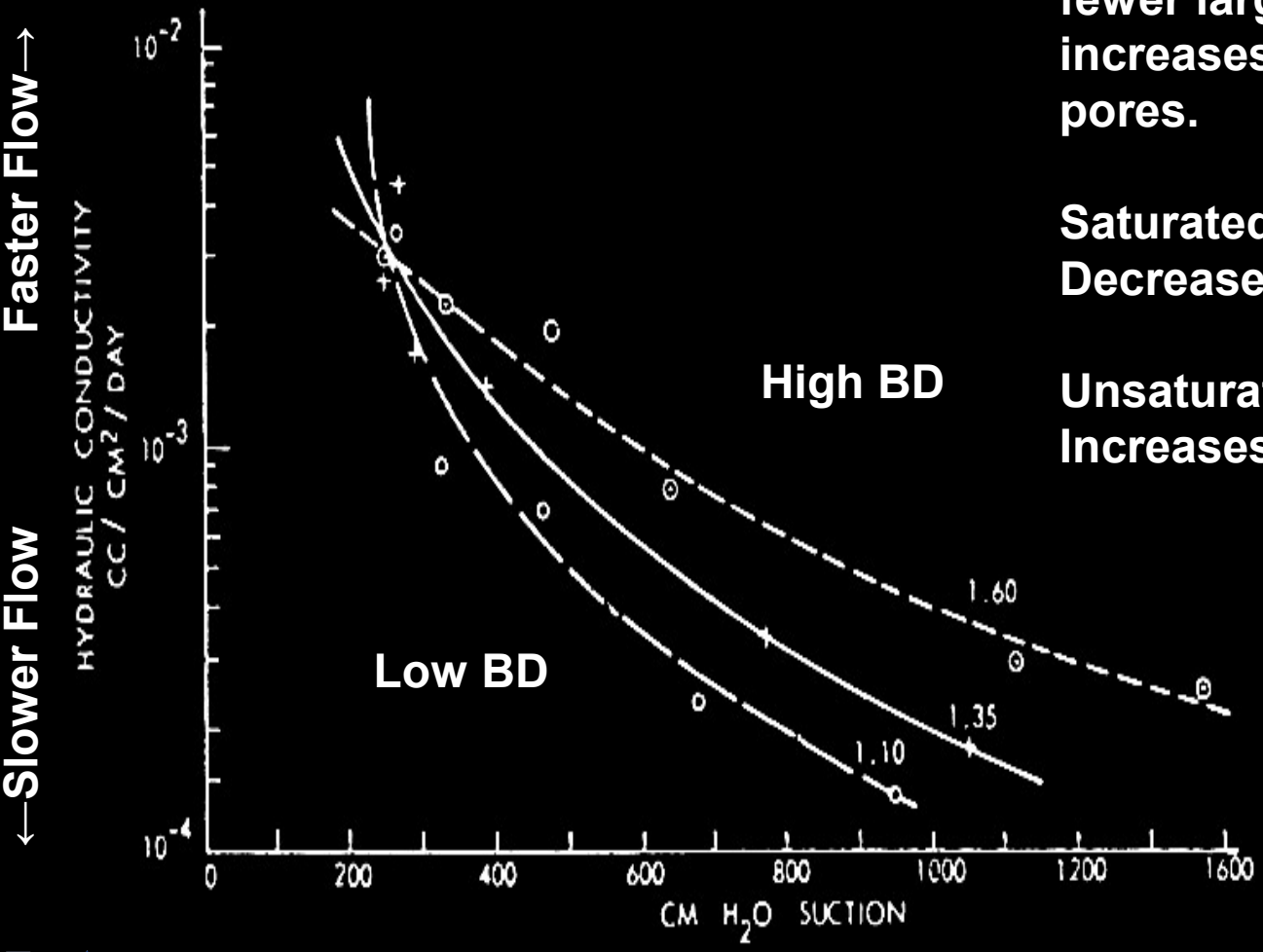
As Compaction Increases:

Flow decreases due to fewer large pores, but flow increases through small pores.

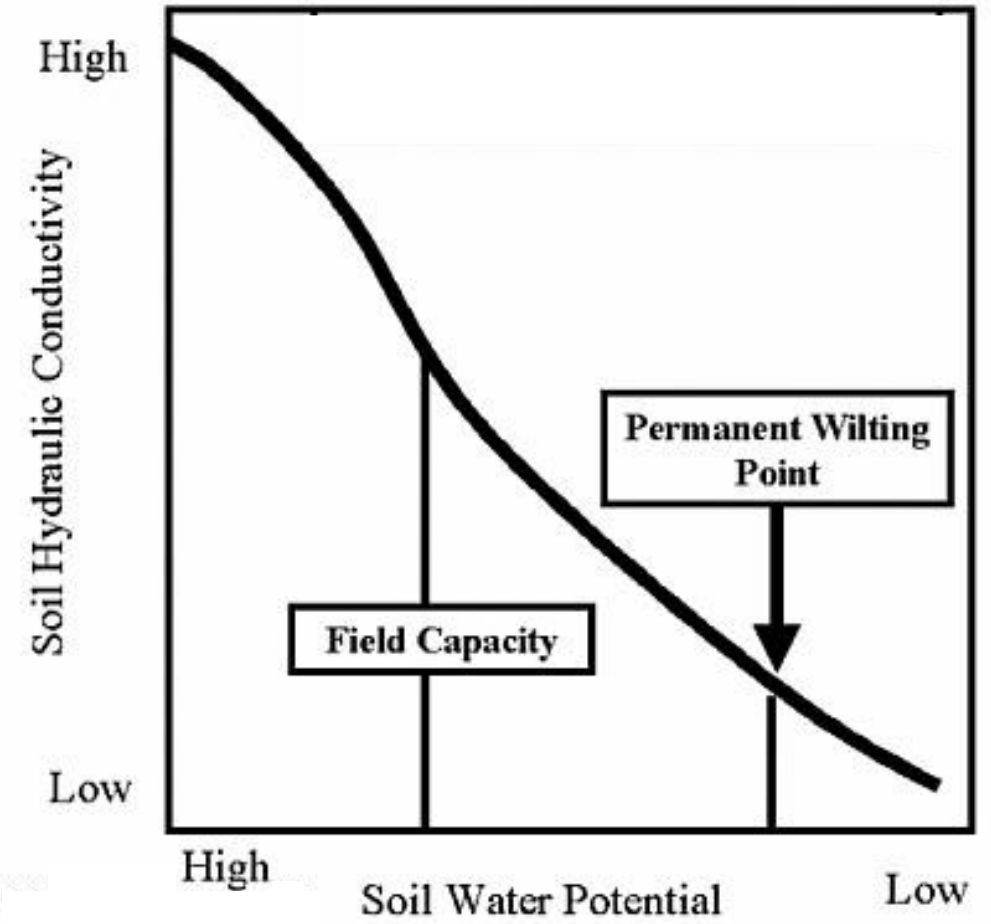
Saturated Conductivity Decreases

Unsaturated Conductivity Increases (to a point)



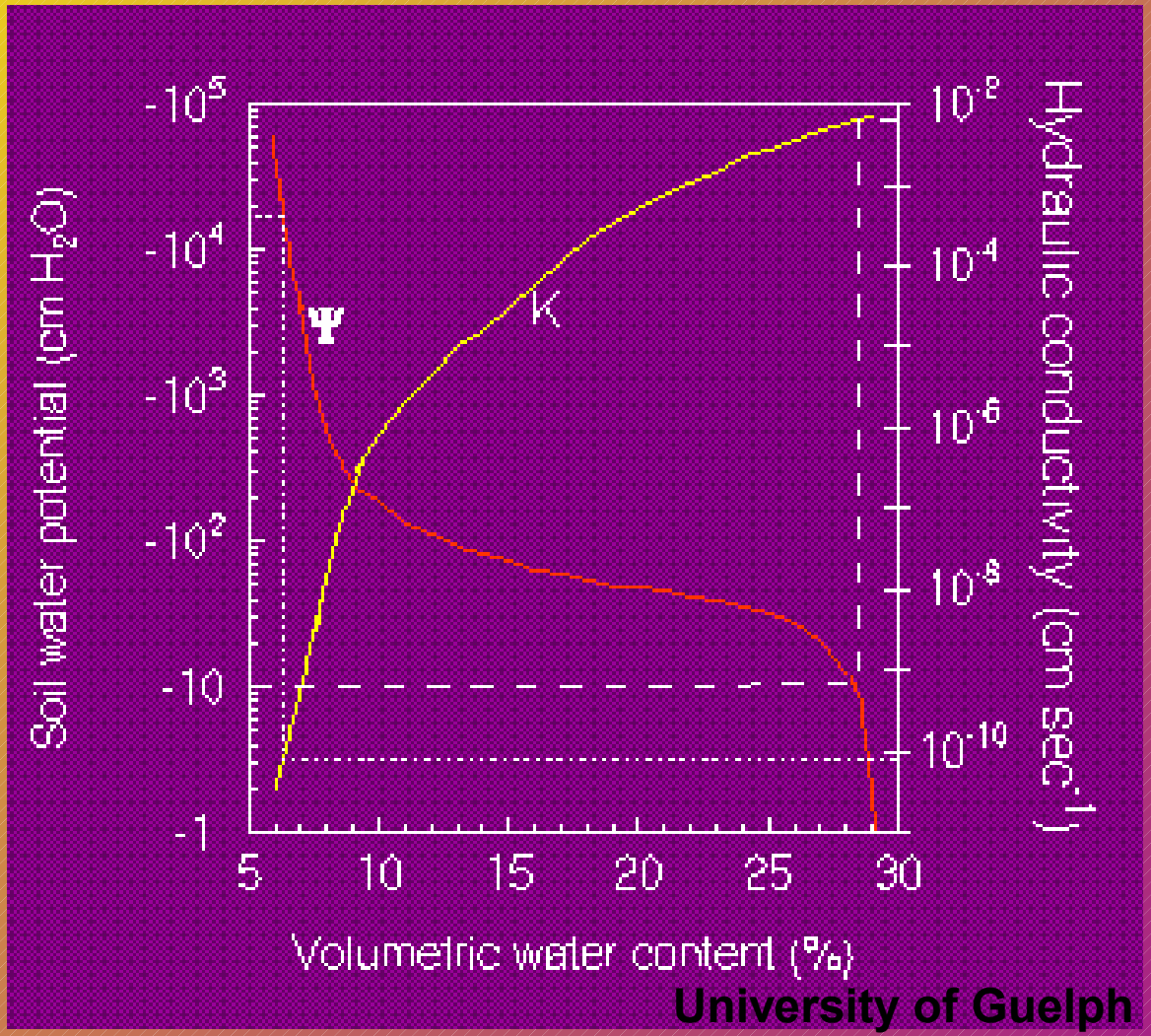
Carleton, 1971

Hydraulic Conductivity & Water Potential



Adapted from University of HI

Volumetric Water Content Effect on Water Potential & Hydraulic Conductivity



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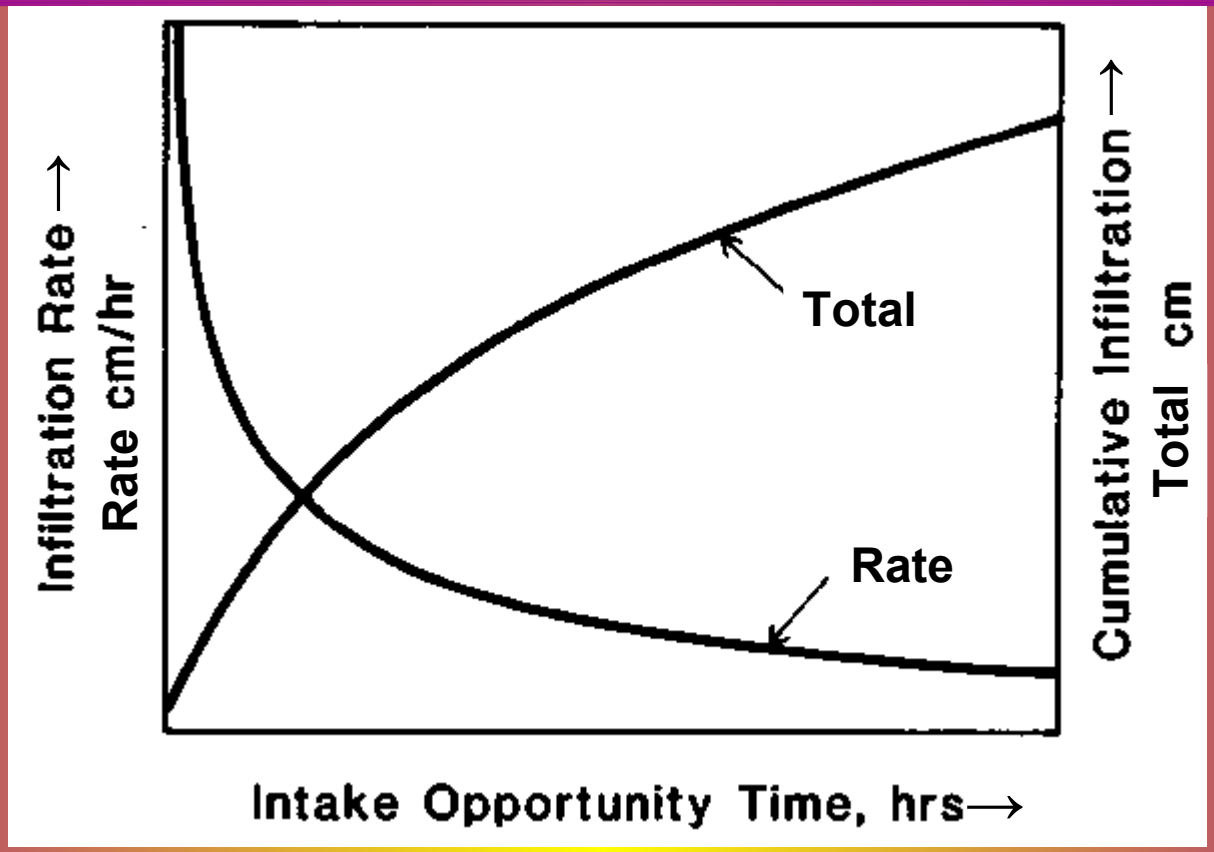
INFILTRATION
Water Entry Into the soil



Adapted from FAO

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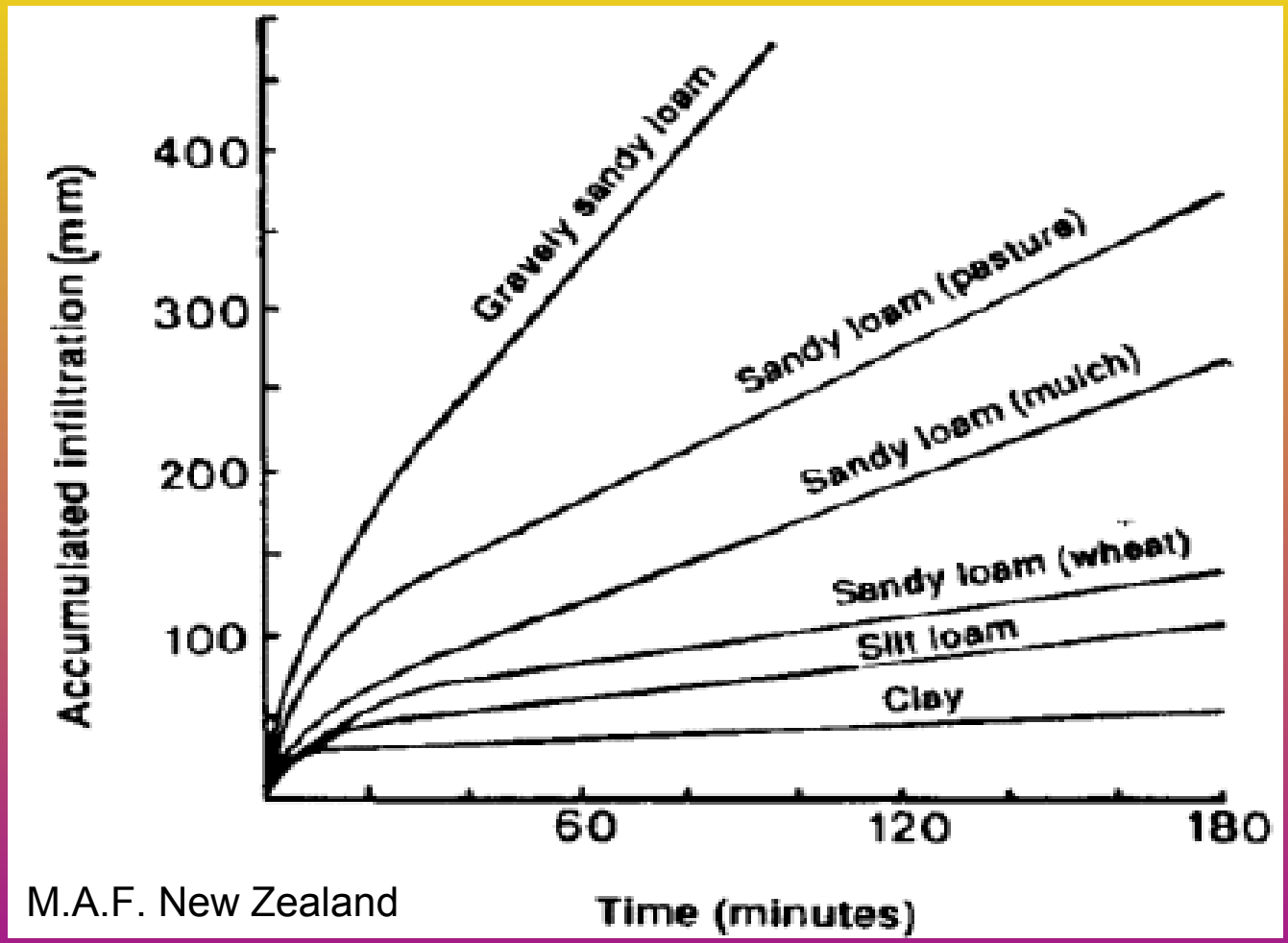
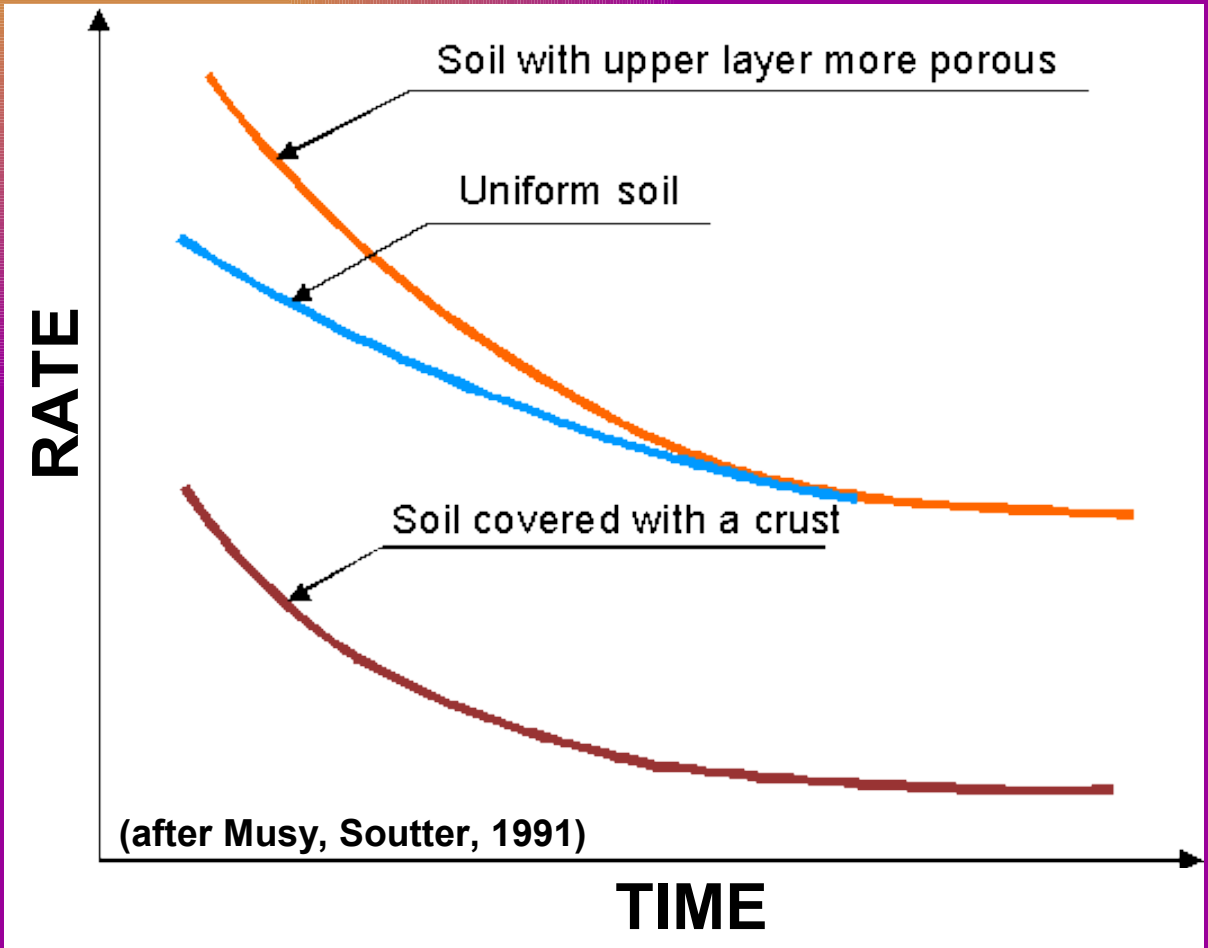
Texture, Structure & Infiltration

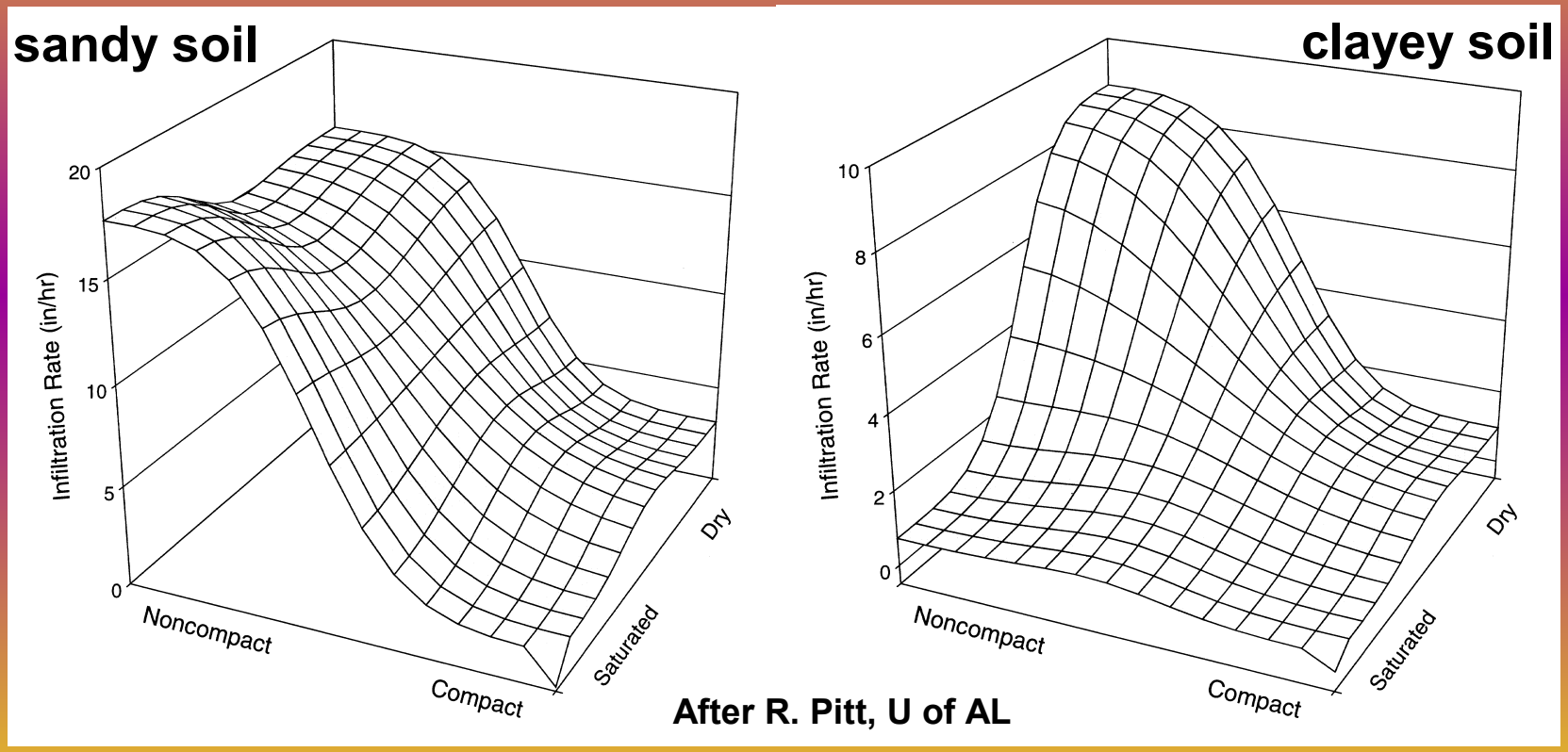


M.A.F. New Zealand

Soil Properties & Infiltration Rate



Structure and Antecedent Water Effects on Infiltration Rate



After R. Pitt, U of AL

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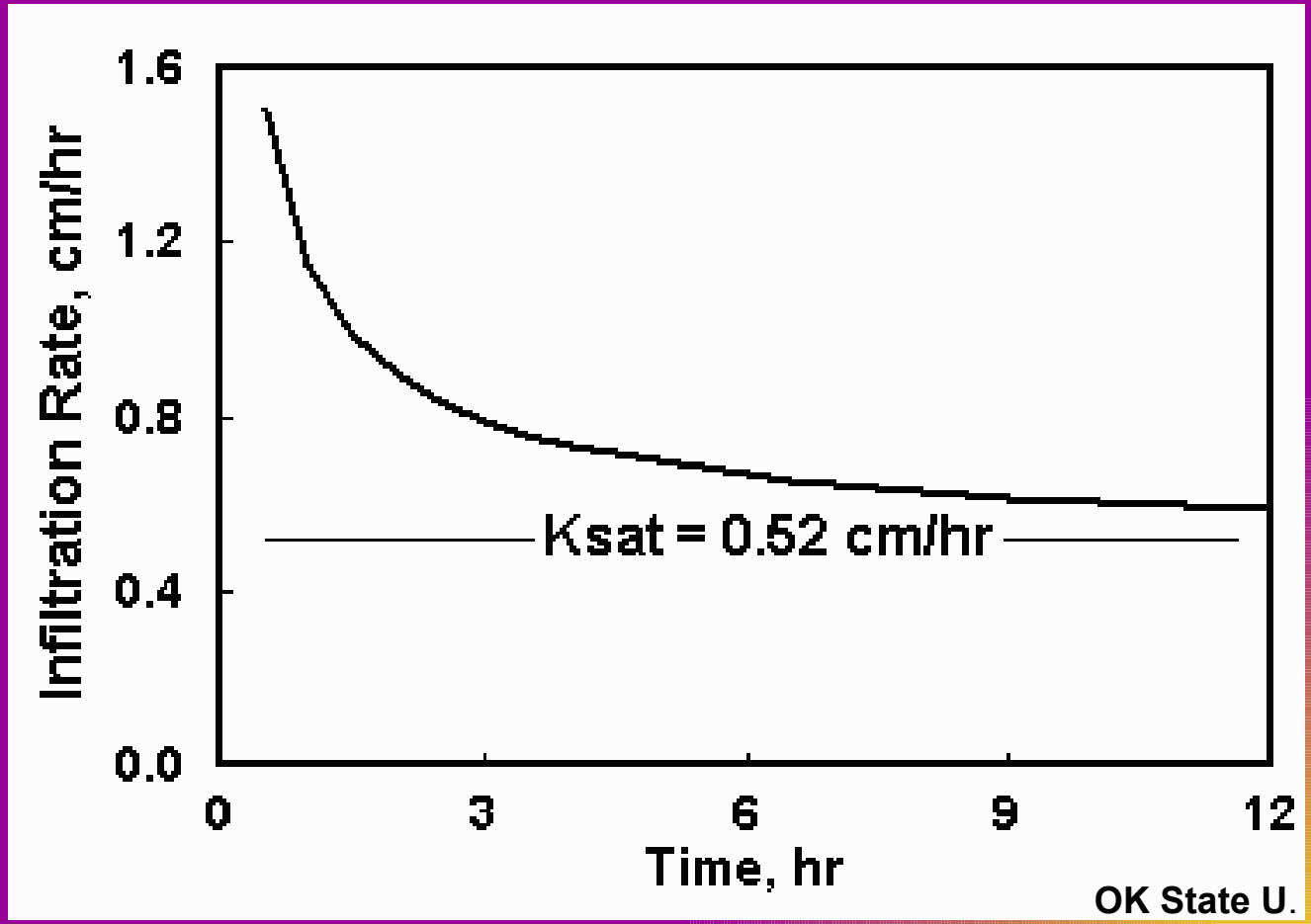
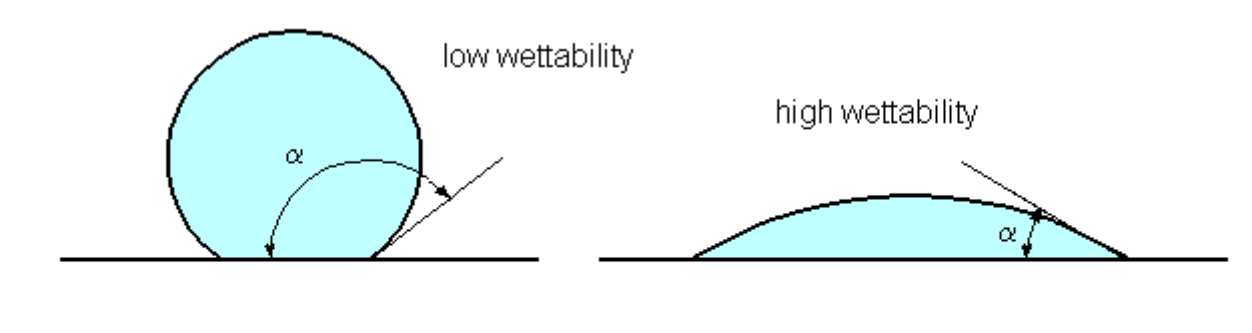
Infiltration Related to Hydraulic Conductivity



Contact Angle, Wetability & Water Drop Penetration Time



Fun Science Gallery

Conceptually related to Infiltration,
but poorly correlated at field, or even plot scale

Water Drop Penetration Time

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Water Drop Penetration Time= A Great Segue to Measurement Considerations

- Measurement Scale: point/field/landscape
- Disturbed, “Undisturbed”, *In Situ*
- Spatial Heterogeneity of Soil Properties
- Relationship of Measured Parameters
- Appropriateness of the measurement to the Question and/or Problem Solution
- Precision vs Accuracy
- Cost and Effectiveness
- Feasibility
- Interpretation

Soil & Soil-Water Sampling

- Where?
- Loose? Cores?
- How Many per Acre?
- How Much?
- How Deep?
- When?
- How Often?
- What Measurements?

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Double Ring Infiltrometers
(Ponded / Free Water / Saturation)

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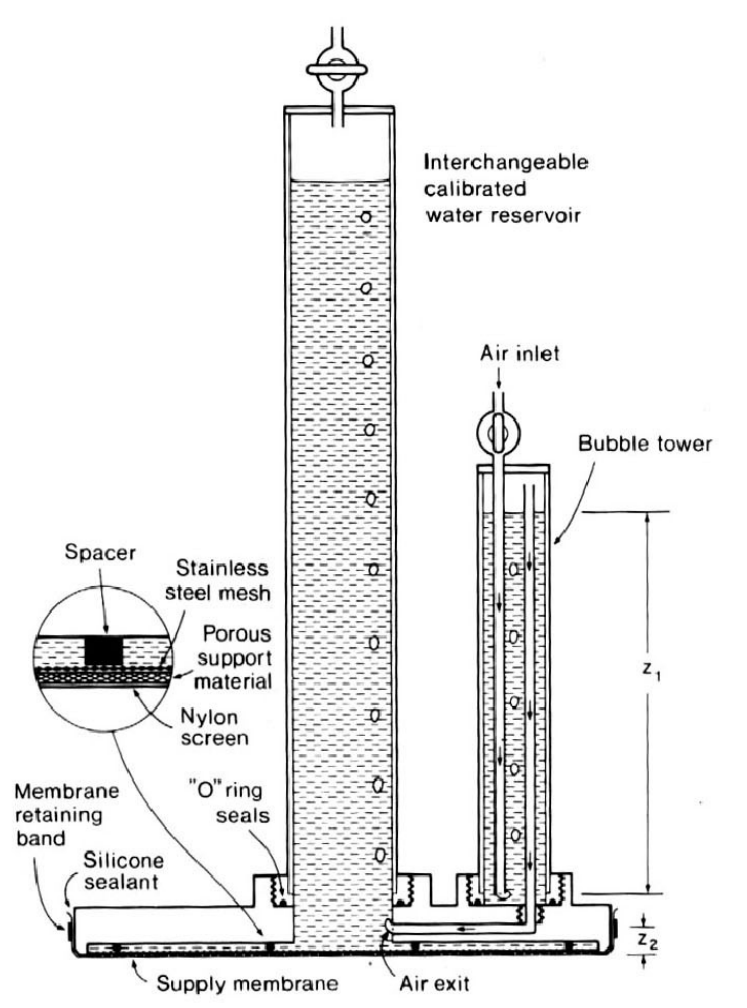
Tension Infiltrometers



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Scale of Measurement

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Pressure Plate Apparatus
Water Retention (volume vs. energy)

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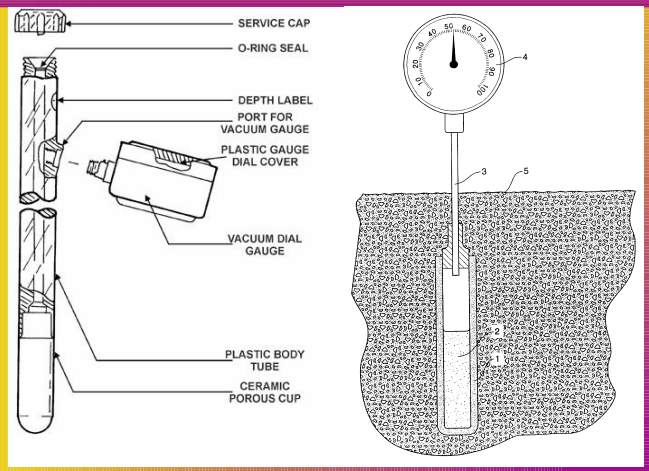
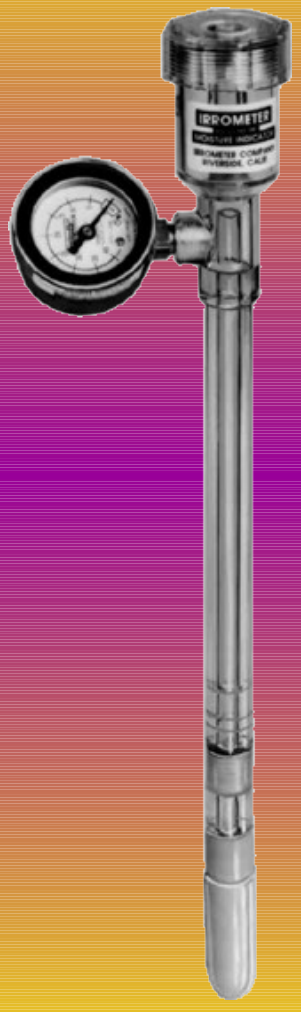
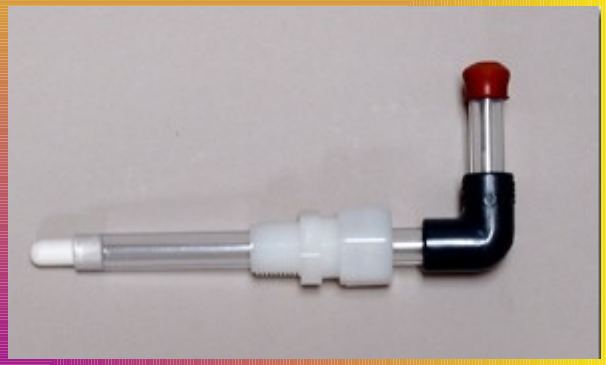
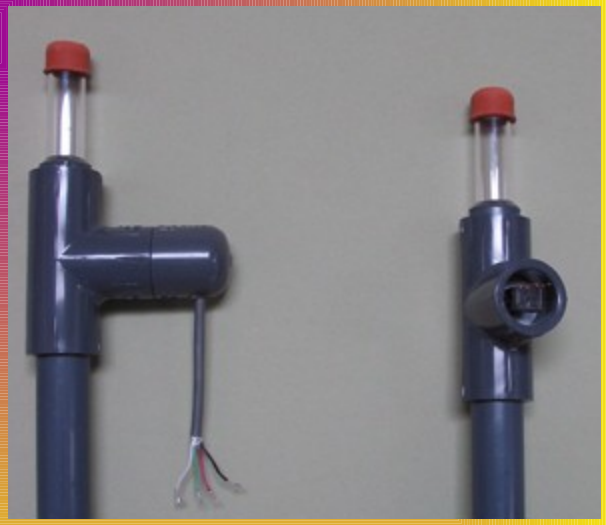
Tensiometer, In Situ, 0 to -0.8 bar









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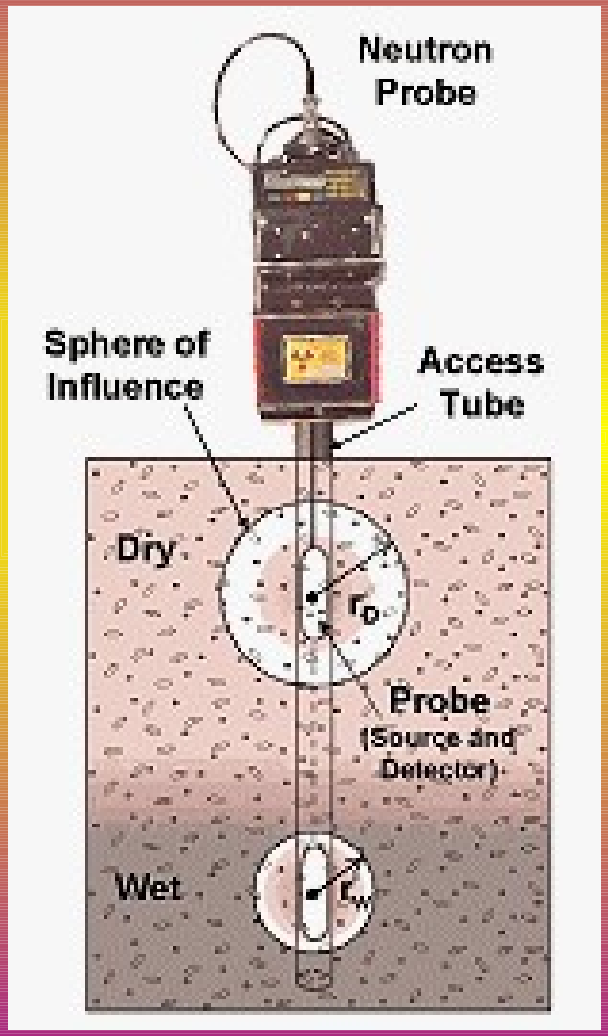
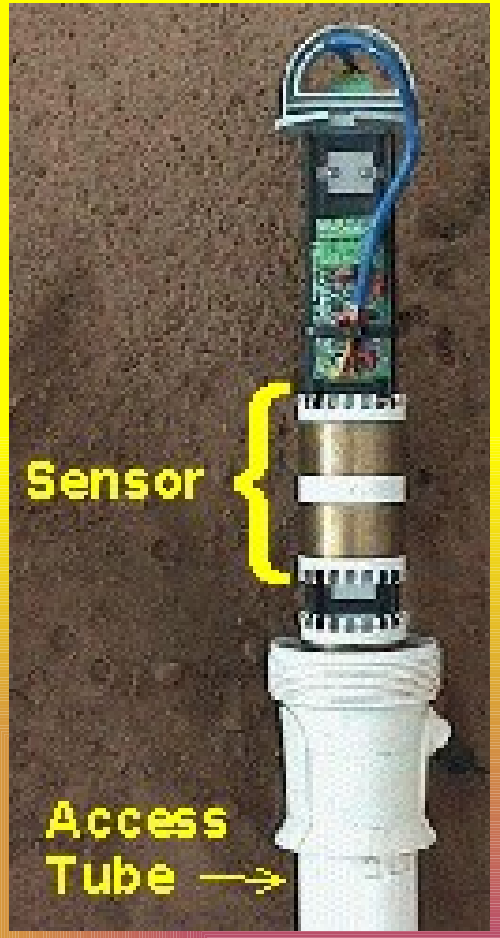
Time Domain Reflectometry - TDR

Resistance Sensors

Neutron Attenuation



Capacitance Probes



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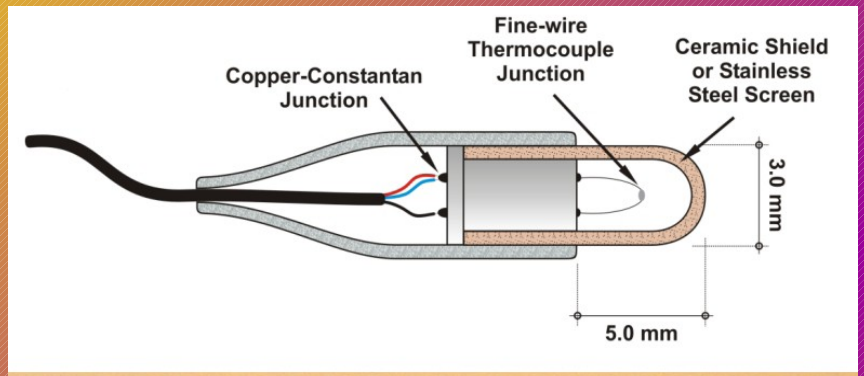
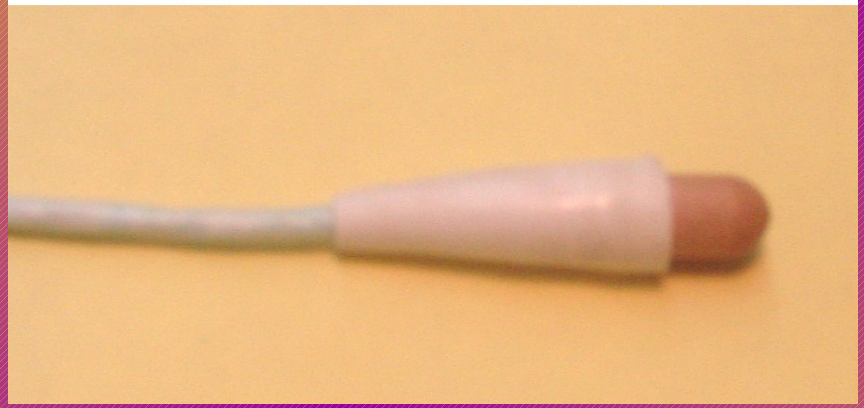
Thermocouple Psychrometers





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Miscible Displacement
(Movement of Solutes with Water)

- Water Flow and Soil Water Content
- Diffusion and Dispersion
- Flow Conditions (Steady vs. Unsteady)
- Pore: Size Distribution, Number, Tortuosity
- Solute Concentrations & Ionic Attributes
- Sorption and Ionic Exchange Phenomena
- Chemical Reactions

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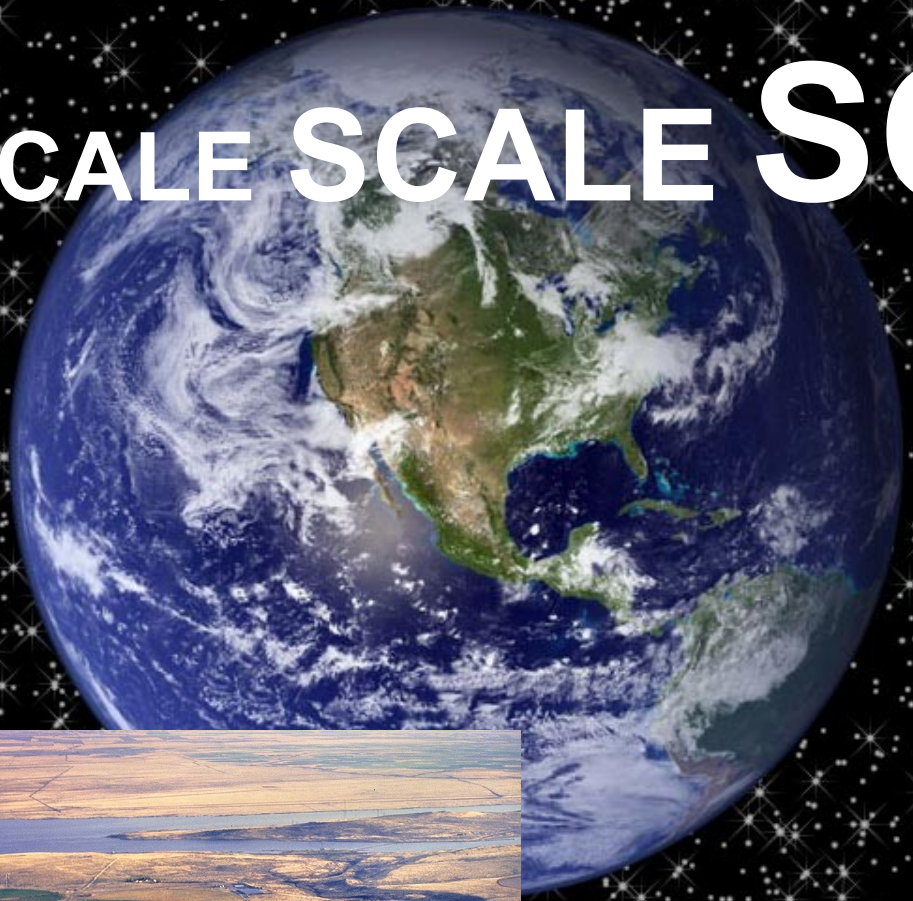
SCALE SCALE SCALE



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Thank You

Questions?

http://sand.nwisrl.ars.usda.gov/indexjs.shtml